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THE GRAPHICS OF THE EFFICIENCIES OF THE STEAM ENGINE.

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Among the many fragments of Rankine's work on the economics of the steam engine which have been left us as nuclei of later detailed and more complete studies, none, perhaps, better illustrates the remarkable perspicacity of the man than his statement of the principle properly governing the adjustment of the best ratio of expansion, and his exemplification of that principle by the application of the touchstone of financial result. James Watt, a century ago, and more (1782), patented his invention of the use of the expansive action of steam in the engine, with the purpose of effecting the most economical possible conversion of thermal into dynamic energy; but he was never able to secure those gains in the practical operation of the machine

which his mathematical computations had indicated as scientifically possible and as practically obtainable. A hundred inventors since the time of Watt have wrecked their fortunes, and thousands of engine builders and users have met with disaster, striking on the same rock. The vast discrepancy between the seemingly exact and positive predictions of the thermo-dynamic and mathematical theory of the engine and its practical results in everyday work have seemed to all the early engineers too great to be attributed to other than defects of construction and to errors in restricting the expansion of steam or in so constructing the machine as to make it impracticable to secure at once considerable expansion and steady motion. For a century it thus happened that efforts were constantly being made by inventors and builders to find some way of grasping that immense profit which was apparently just within reach by the simultaneous rise of steam pressures and the expansion ratio. It is only recently that we have learned precisely where the difficulties lie, and what must be the direction of improvement to insure the remedy of the still existing defects and further approximation to the thermo-dynamic conditions and to those results which are the ultimate object of every great invention relating to this wonderful machine.

Watt discovered the facts which are now known to constitute the obstacle to success in the endeavor to carry out his principle and to gain full advantage in transformation of the heat-energy stored in steam; but he exhausted all his ingenuity in the endeavor to remove what he thought the main barrier to complete utilization of his idea—irregularity of action of a piston subjected to varying pressures—and probably never discovered that, with ever so smooth a motion, profitable expansion must be enormously restricted by that phenomenon, the investigation of which was the subject of his very first experiments with the old Newcomen model of the University of Glasgow. It was reserved for Daniel Kinnear Clark, in England (1852), for Hirn, in France (1855), and for Isherwood, in the United States (1860), to show that the primary source of this restriction of profit-

able expansion was to be found in the fact that the internal wastes by condensation of steam, consequent upon the heat-conducting character of the cylinder walls—to "cylinder condensation" as it is now generally, though, perhaps, inelegantly, termed—increase more rapidly than the gain by expansion, thus giving a low ratio of maximum economic value. Rankine and Clausius, and Thomson and Zeuner, built up the whole thermo-dynamic theory of the heat-engines; but it was only after a quarter of a century had passed that the differences between the ideal and the real heat-engines came to be fully understood, and that their effect upon the economical working of the machine was recognized. Rankine earned added fame by his declaration of the principles of finance bearing upon the case and by showing that here, as in every other task set the engineer, the results must be gauged by the final measure of all engineering—the work accomplished by the unit of coin paid out; but the effect of the Watt phenomenon did not enter into his computations, and its extraordinary effect upon the proportions of the steam engine remained to be revealed by the work of the last and the current decades. The essential principles affecting the proportions of the engine which will give the best results, all things considered, are probably all now familiar to every well-informed engineer and to many contemporary thermo-dynamists; and the exact methods of investigation of the subject will become equally familiar to all when the now numerous researches in the physics and the economics of the case, now in progress in the hands of numberless engineers and men of science, shall have fully revealed the data needed for their development.

Graphical methods of representation are usually more intelligible to the engineer than are the algebraic processes; and this is especially true of the engineer whose genius lies in the direction of invention and of construction, rather than of theoretical investigation, and where the conditions to be studied and examined with reference to their relative interactions are numerous and where those mutual influences are obscure. An algebraic equation gives, in its solu-

tion, a single isolated datum; a curve in a diagram, the equation of which curve is known and permits its construction, exhibits an infinite number of successive values simultaneously, and illustrates, at the same time, the method of variation of those data and the presence or absence of maxima and minima. The diagram itself may present to the mind at a single glance the whole succession of phenomena in a series, or a complete cycle of operations involving the solutions of various equations, and for numerous different values if algebraic methods are adopted for the case. A half-dozen computations and a few strokes of the pencil, on the other hand, reveal, often, all the details of operation of a complicated system, and tell just where and how the engineer may look for results of maximum possible value. For the cases to be studied in the present instance, we shall probably find graphical methods the only practically available system of revelation of the information and the facts sought. It is for this reason, and because they are also vastly more satisfactory in their legibility and comprehensiveness, that they are adopted in the work which follows.

The Distribution of Energy supplied the steam engine is easily stated in a general way; but the exact distribution into utilized power and wasted energies is not always readily ascertainable, even with modern facilities for their measurement. Assuming this analysis to have been effected in any given case, as for a modern "high-speed" engine of moderate power, and working with high steam-pressure, some such balance-sheet as the following would be obtainable. Should the columns fail to balance, it would indicate either that a false measurement had been made, that the errors of careful observation, even, were sensible and perhaps cumulative, or that some source of waste had escaped observation altogether, as often did, in fact, the internal thermal wastes, during the greater part of the history of the machine, and up to within a few years.

BALANCE SHEET OF HIGH-SPEED ENGINE.

RECEIVED.	*Per cent.*	EXPENDED.	*Per cent.*
Energy stored in steam produced in the boiler and transferred to the engine	100	Utilized by conversion into dynamic energy at the engine .	9
		Wasted by friction	1
Total	100	Indicated Power	10
		External thermal waste	2
		Thermo-dynamic wastes . . .	60
		Internal thermal waste	28
		Total	100

Of the several quantities in the right-hand column, the first is easily and exactly calculable, as it is a purely thermo-dynamic problem, and capable of precise solution. The second item may be approximately computed, or deduced by reference to the experimental determinations of friction losses exhibited in the operation of similar engines. The first is the dynamometric or "brake" power of the engine, and the second is measured by the difference between the "indicated" and the "brake" powers. The fourth is heat lost by conduction and radiation, and may be computed or observed in any case with sufficient accuracy for all practical purposes of the engineer, and for the present case. The fifth is the necessarily rejected heat of the thermo-dynamic operation, is dependent upon the cycle adopted, the range of temperature worked through in the conversion of energy, and is precisely computable. The last, the internal wastes of heat by "cylinder condensation," may be accurately measured in the case of the engine constructed and in operation, and can be approximately computed or may be deduced by reference to the performance of other engines, where the results sought are for the case of an engine proposed and to be designed. We make these measurements or computations, or both, for any number of sets of conditions, and may establish a curve for each of these elements of the problem, the ordinates of which may be made the costs of the energy represented, and the abscissæ may be taken as the measures of the steam used or any convenient quantity defining the conditions of the case, as, in

the cases to be here used in illustration, the ratio of expansion adopted, unity weight or volume of steam being always taken into the engine at the point of cut-off.

The measure of cost here to be taken is the number of pounds of steam demanded per horse-power per hour to supply the energy utilized or wasted, as the case may be. With steam at a pressure of 120 pounds absolute, 105 by gauge, nearly, and with a back pressure of three pounds above vacuum, clearance being negligeable and the engine well jacketed, the quantity of steam demanded for efficiency unity would be about two and one-half pounds per hour per horse-power, and, for any other efficiency, 2·5 divided by that efficiency, nearly. This quantity, as computed for the ideal case, the ratio of expansion being fixed, is invariable and incapable of modification by any human power. The wastes, other than thermo-dynamic, which latter waste is also inalterable, are capable of amelioration by various expedients, some of which are easily applicable, others difficult and as yet impracticable.

It is thus evident that it is by the amelioration of wastes in the ordinary steam engine that we are to advance in its improvement, if at all, aside from the gain to be effected by that increase of temperature range in expansion, which is the method of thermo-dynamic improvement available. It is in the reduction of extrathermo-dynamic wastes that we are to seek the most fruitful ways of promoting the economy of operation of the heat-engines of whatever kind, while the increase of thermo-dynamic efficiency and the reduction of thermo-dynamic losses will probably occur continually, but slowly, up to some as yet undetermined limit, which limit is, nevertheless, probably not very far distant. Both the thermo-dynamic improvement and the gain by reduction of extra thermo-dynamic wastes must be looked upon as legitimate ways of further improvement of the steam engine as a heat-engine, as a transformer of thermal energy into dynamic form; but the inaccessibility of the zero of the absolute thermometric scale renders the former comparatively unpromising of result, while the interception of external heat losses, the abolition of internal heat wastes

due to the heat-conducting character of the cylinder walls, and the elimination of friction, are at present more simple and promising directions of advance.

As will be presently seen, each of the extra thermo-dynamic wastes becomes a larger and larger tax upon the thermo-dynamic machine as the latter becomes more efficient through extended expansion, and each, acting by itself, would, if carried sufficiently far, place a limit to economic heat-conversion by such expansion; which limit is the earlier reached as the waste is greater. Thus, with prolonged expansion, a time would always come when further expansion of the steam would develop less power than would be, at that instant, required to overcome the resistance of friction; and, from that point on, the power exerted by the machine upon the working machinery would be a negative quantity. Similarly, external wastes of heat might, beyond a given ratio of expansion, amount to more than the quantity usefully converted, and efficiency would thus again be made negative. Internal heat wastes in this manner render the total ultimate efficiency of the engine a negative quantity at a comparatively early stage in expansion, as these wastes are great at low ratios even, and are a rapidly increasing fraction of the energy supplied with increasing expansion. Thus the magnitude of the ratio of expansion at which final total efficiency becomes a maximum is a gauge of the extent to which avoidable forms of waste exist in the engine, and of the success attained in the design, construction and operation of the engine. That engine which gives its best effect at the highest ratio of expansion is, other things equal, the best engine, viewed from the standpoint of physical perfection. This is perhaps best shown by the diagram herewith presented.

In figure 1, let the ordinates of the various curves be made proportional to the weights of steam employed per horse-power and per hour, under the conditions assumed in the construction of each of the several curves, and let the abscissæ measure the simultaneous values of the ratios of expansion in the given engine, and with the initial and back pressures, as here assumed—120 and three pounds,

respectively, above vacuum. Compute, first, the quantity of steam required for the "ideal case" at each of these ratios of expansion, and construct the lower curve of the series by passing it through the several computed points. Similarly, compute, or find by reference to results of experiment, the additional and total quantities demanded for the engine when the wastes due friction are taken into account, and thus obtain the second curve. Next add the weights of steam required to supply the heat wasted externally by conduction and radiation, and, as a final determination, find the internal wastes by the action of the cylinder walls, thus ascertaining the locus of the upper limiting curve of the series.

The lower line is obtained by the method of Rankine, and accurately represents the efficiencies and the costs of power for the ideal representative case taken. It is seen that the steam expended varies from about 40 pounds per horse-power and per hour at full stroke, to 20 at 3·5 expansions, to 16 at a ratio of expansion of 5, to 12 at 12 expansions, and about 10 pounds at a ratio of 20. The gain continues indefinitely, but at a decreasing rate, until a ratio of about 40 brings us to the limit at which the expansion line begins to fall below the back pressure line. Were there no wastes of extra thermo-dynamic character, this would be the method of operation of the engine which would insure highest efficiency and highest "duty." The friction loss in the case here taken, costs a quantity of steam which is decreased with the enhanced efficiencies of higher expansions, is but little affected by changing loads and power, and which, as a percentage of ideal costs, increases constantly with increasing expansion and decreasing power. It is thus found to place a limit to gain, as here taken, at about twenty-five expansions, and adds, throughout the whole range, not far from three pounds of steam per hour and per horse-power to the costs of useful work. External heat wastes still further exaggerate costs and restrict the profitable expansive action of the engine and a ratio of twenty is found on the curve to be as much as can be employed to advantage when all these wastes are taken into

account. Finally, taking up the internal heat wastes by action of the metallic surfaces enclosing the fluid, and assuming, as here, that the engine is of such size and character as to waste, in spite of jacket-action, from twenty per cent. at full stroke, to fifty per cent. at seven expansions, and still higher proportions at greater ratios, the proportions found actually wasted in, for example, the Sandy Hook experiments reported by the writer to the A. S. M. E., some years ago, it is found that a maximum efficiency is attained, as shown on the upper line, at about seven expansions, or at the point experimentally found for a more efficient engine, operated at a lower pressure, by Hirn and Hallauer. This is probably as large a loss, and gives as radical an illustration of the facts of such cases, as can be fairly expected. No well-designed and properly constructed engine should give a higher curve of final efficiency than is here presented, unless of very small size or working under peculiarly disadvantageous circumstances.

Whatever the form or dimensions of the engine, such construction of its several elements of efficiency as is here exemplified will exhibit the facts in which the designer is most interested, and show the costs of power and the most economical adjustment for high duty. All the thermodynamic, and all the thermal, and all the dynamic elements are here brought into view, and all measures are taken by a common and intelligible scale. The scale actually to be adopted will depend upon circumstances. Where the steam is supplied under different conditions, and thus may have a variable measure of intrinsic or conventional value, the vertical scale should be made in thermal units, rather than weights of steam. In some cases it should be made a scale of coal-weights, while in the solution of some of the most important problems presenting themselves to the engineer, this scale should be one of money-costs.

The Comparison of Various Types of Engine may be made by these graphical methods with the greatest ease and with most satisfactory results. Every essential element of economical operation being thus capable of representation on a common scale, the construction of such a diagram

as is here illustrated and described for each permits the selection of the machine likely, on the whole, to prove best; and we are thus enabled to identify the best adjustment of each and to make the comparison of a pair or of a series of available designs under their several individually best conditions of working. Adhering to the case thus far studied, that of the simple engine, it may be required to ascertain which of a number of machines of stated and required power, but differing in proportions of stroke and diameter of cylinder, or in speed of piston and of rotation, or even simply in clearness, is most desirable. The construction, on a common scale, of a set of these diagrams will reveal to the eye and at a glance the probably best design. The loss by clearance is treated precisely like the wastes by external loss of heat or by internal condensation or leakage, and all may, as in fact illustrated above, be taken as a common internal waste, since it often happens as here that they cannot well be separated with exactness. The best practical method of making the comparison is perhaps that of making the diagrams on tracing paper or cloth and superposing them, one upon the other in pairs, eliminating, one after another, the least desirable cases.

Compound or "Multiple-Expansion" Engines afford the most interesting and probably the most useful applications of such methods of graphical representation of problems of this sort. In such comparisons as have been just referred to, when multiple-expansion, series-expansion—or cascade-expansion, as French writers sometimes call it—is to be considered, it becomes especially important to ascertain not only what relations of efficiency exist at the best adjustment of each, but often even more important to determine the method of variation of efficiencies with varying expansion, and the relative values of each type throughout their respective as well as their common ranges of working. This process of complete study which, ordinarily, is most laborious and troublesome—when, especially, their respective best conditions of operation are to be identified and compared—becomes easy, interesting and exact when the graphical process can be accurately carried into effect. It then

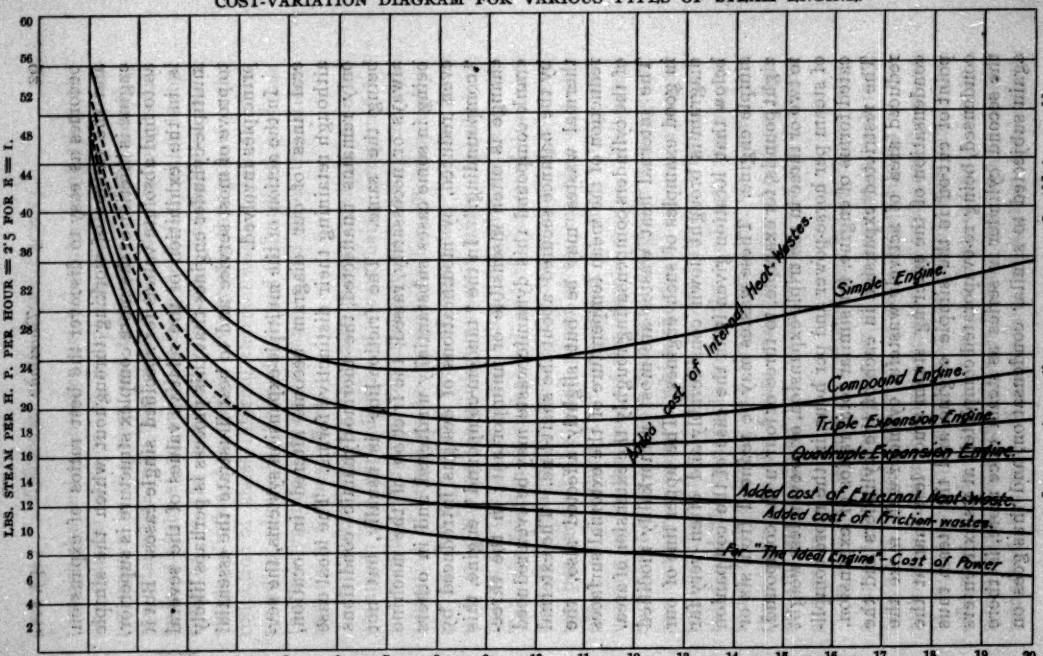


FIG I.—STEAM DRY AND SATURATED THROUGHOUT THE STROKE.—ENGINES EFFECTIVELY JACKETED.

becomes as easy to discover the best ratios of expansion, and the ranges of working throughout which the simple engine is inferior or the more complex structure is superior, as to find absolute values for specified single cases. But it is in the exhibition of the relative values of the several multiple-cylinder engines that this process is perhaps likely to prove of most service and to best illustrate the essential principles involved.

In the action of the multiple-expansion systems, the several lines of our diagram become altered in location, although retaining their distinctive forms. The ideal case only remains unaffected, the thermo-dynamic conditions being the same. The friction-line is usually, but not always or necessarily, raised; the friction of the machine being in some cases substantially unaltered, and in others even reduced, by modifications of designs introduced by "compounding." In the "tandem-compound" engine, this change is often insensible or unimportant; in the three-crank compound this dynamic waste may be even reduced by the balance secured about the shaft-line. The external thermal wastes may be but slightly affected also, the reduction of the mean temperature of the external surfaces of the cylinders compensating roughly the extension of area. The internal heat wastes are most remarkably modified in good examples of such engines. The upper line of our diagram is brought down considerably and often very far below that location given it in the case of the companion simple engine. These wastes may be reduced from six or eight pounds, for example, to three or four in the compound, to two or three in the triple-expansion, or to even less weight of steam per horse-power and per hour, in the more complicated forms of engine, for similar total ratios of expansion. The restricted expansion in each of the cylinders and the reduced area of actively wasteful cylinder-wall, make the condensation of the entering steam much less than at the point of cut-off in the simple engine, and the steam thus condensed, being re-evaporated completely at its exit, enters the second cylinder in series as steam once more, is there again subjected to similar condensation, and thus goes on

through the series, however extensive, the waste from the one cylinder more or less completely meeting the demand for wastes in the next, and thus approximately reducing the total waste from this action to that comparatively small fraction of the steam supplied from the boiler, which is represented by the comparatively small condensation in a single cylinder of the series. Every step thus gained in the reduction of these internal thermal wastes permits corresponding advance to be made toward full utilization of the thermo-dynamic gain due expansion and raises the ratio of expansion for best effect.

In illustration: let the same thermo-dynamic case be assumed; the expenditures of steam being computed by the familiar equations for efficiency, and taking the consumption of steam to be 2·5 pounds for efficiency unity; giving, for any given ratio of expansion, not far from $w = 40 \surd r$, as the minimum cost in steam expended, as before, for the ranges of expansion usual with such engines. Take the friction as unchanged and the external losses of heat as substantially constant, the one amounting to about ten per cent. of the rated power of the machine and the other as one-third that proportion, at that rating, and varying as in the case of the simple engine. Following experience with the most successful designs of mill-engines, and comparing cases in which the double-expansion engine reduces the internal wastes to one-half, the triple to one-third, and the quadruple to nearly one-fourth the magnitudes distinguishing our simple machine, we obtain the three curves in the figure lying between the upper line already obtained and the lower three lines of the diagram as first traced.

In each case we find the internal heat wastes constituting a heavy tax upon the operation of the engine; in each they become a larger proportion of total expenditures as the ratio of expansion becomes greater; in each case the point of minimum expenditure and the ordinate of maximum efficiency recede further from the best ordinate for the simple machine, as these losses become less; and, as already remarked, the ratio of expansion for highest total effect

becomes a gauge of the value of the type of engine studied. While the simple engine did its best work at a ratio of 7—all these machines are assumed to be jacketed—the compound raises the figure to 10; the triple-expansion to 12 or 13, and the quadruple-expansion engine does its best duty at a ratio not far from 18. With larger and faster engines, these values of the ratio of maximum effect will be found

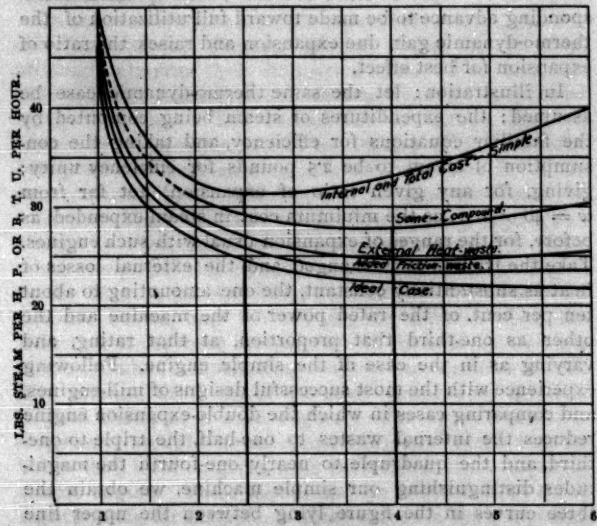


FIG. 2. LOCOMOTIVE.

SIMPLE ENGINE UNJACKETED. COMPOUND ENGINE JACKETED.

Steam at $p_1 = 120$ lbs. absolute; $p_2 = 20$.

still more distributed, and will assume still higher values; but 7 or 8, 10 to 12, 13 to 15, and 18 to 20, are probable fair maxima, respectively, in modern good practice with the assumed pressure, for the several types of machine above taken.

Comparing the range of competitive operation, it is seen that, in these particular cases, the compound competes with

the simple throughout the range from the ratio 4 to some point beyond our maximum limit on the diagram; that the triple-expansion competes with the compound from $r = 5{\cdot}5$, and with the simple between 3·5 and the maximum; and that the quadruple similarly competes with the simple between 3 and the limit, with the triple between 5 and the extreme, and with the compound between 3·75 and 20 or more. It is assumed, in each comparison, that the basis of the competition is the duty, or the steam required per horse-power per hour. The simple engine competes, at its best ratio, with the compound and other engines only when the latter are working at abnormally low ratios of expansion, and each multiple-cylinder machine shows superiority over the preceding in our list at expansions which are always less than the best ratios of the simpler engine. These comparisons, however, obviously may result very differently when the complication introduced with the multiple-cylinder engine throws up the lines representing friction and external wastes to such height as to make the loss of energy in these directions exceed the gain by reduced internal wastes, and thus carries the upper line of the representative diagram for the latter above the line of total cost for the simpler machine with which it is compared. Very different and often very disappointing and unexpected results may thus follow where the engines are not suitably adapted to their working conditions, or when they are unskilfully designed and proportioned.

In all cases, whatever the type of engine, it is likely to be found that the best results are only to be secured when the extra thermo-dynamic wastes of the machine are intelligently treated and made as small as practicable. It is in this direction that the indications are that the greatest advances are to be made in the immediate future of the history of the steam engine.

Specific Applications of the principles illustrated in the general case just presented will be easily effected where the data are available. For example, let figure 2 represent the distribution of useful energies and wastes in the case of a locomotive. The thermo-dynamic case is com-

puted, as per Rankine and as in the earlier work of the author.* The steam consumption is found by experiment to be approximately measured by $w = 45 / \sqrt{r}$. This quantity is increased, when the friction of the engine is taken into account by about ten per cent. at ordinary expansions, and the external heat wastes add a very nearly equal amount; both these wastes, however, being found by experience to be variable slightly with varying power and to be somewhat less as an absolute amount and greater relatively with decreasing expansion. Friction is taken as six per cent. of the full power, at full stroke, heat waste as 0·5 B. T. U. per square foot per hour per degree difference of temperature between the internal and the external temperatures. Adding the internal wastes by condensation, leakage, clearance and wire-drawing, following Clark for the first-mentioned up to the middle of our range and later practice beyond, we obtain the upper curve and find our profitable expansion restricted to about $r = 2{\cdot}5$; which accords with general experience from Clark's earliest work to the present time. But, should these last wastes be decreased by compounding or superheating, as is known to be practicable, to one-half their present amount, the limit-curve would fall to the second line, and the allowable ratio of expansion for highest duty and lowest consumption of fuel in regular work would fall correspondingly, giving a higher ratio $r = 4$ or 5, and a consumption of fuel or of steam more nearly three than four, and twenty-five than thirty-two, as the first set of figures would probably read. In other words, the gain would be not far from twenty-five per cent. Both the first and last results have been bettered by engines of each type; but the relative standing of the two should be very much as here indicated.

The two cases above studied are those of engines working under what is generally considered high steam-pressure. The following will illustrate the operation of the older type of machine, simple, unjacketed, condensing, with steam at sixty pounds absolute, forty-five by gauge, nearly. It is

* Rankine, p. 192, et seq.; Thurston's Manual, vol. i, arts. 116, 117, and especially 123, 137.

the engine employed for marine work a generation ago and of which numerous examples survive. In the figure, the lower curve, as before, represents the ideal thermo-dynamic

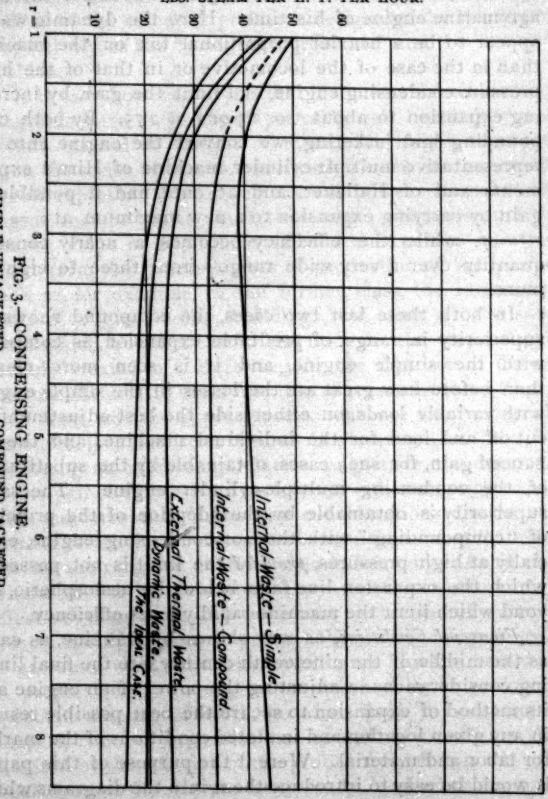


FIG. 3.—CONDENSING ENGINE.
SIMPLE UNJACKETED. COMPOUND JACKETED.
Steam at $p_1 = 60$ lbs. absolute; $p_6 = 4$.

case. The consumption of steam, assuming the temperature of the hot well and feed such that 2·5 pounds would be demanded per hour per horse-power for efficiency unity, is

again about $w = 40 / \sqrt[4]{r}$, and varies between 40 at full stroke to 20 at 3·5 $\sqrt[4]{4}$ expansions and 15 at $r = 8$. Internal and external wastes are computed as before, and the internal wastes are taken as found by Isherwood for the average marine engine of his time. Here the dynamic wastes appear to be a heavier proportional tax on the machine than in the case of the locomotive or in that of the high-pressure condensing engine, and limit the gain by increasing expansion to about $r = 2{\cdot}5$ or $r = 2{\cdot}75$. By both compounding and jacketing, we convert the engine into the representative multiple-cylinder machine of Hirn's experiments and of Hallauer, and at once find it possible to gain by carrying expansion to a new maximum at $r = 6$ or $r = 7$, while the efficiency becomes a nearly constant quantity over a very wide range—from three to eight or more.

In both these last two cases, the compound shows its superiority in range of profitable expansion, as compared with the simple engine, and it is seen more clearly than before how great are the losses in the simple engine with variable loads, on either side the best adjustment of cut-off and load for the individual machine, and the enhanced gain, for such cases, obtainable by the substitution of the condensing multiple-cylinder engine. The same superiority is obtainable by the adoption of the principle of "compounding" with the non-condensing engine, especially at high pressures, *provided* the limit is not passed at which the expansion line falls below the atmospheric, beyond which limit the machine rapidly loses efficiency.

Financial Conditions, as was shown by Rankine, as early as the middle of the nineteenth century, are the final limiting considerations in adjusting the power of an engine and its method of expansion to secure the best possible results in any given location and in stated conditions of the market for labor and material. Were it the purpose of this paper, it would be easy to introduce them into the diagrams which have been given to illustrate purely physical conditions; but these may perhaps be treated more conveniently by the methods earlier developed by the writer, and in which all

these obstructive elements and their varying effects are so treated as to permit both graphical and analytical deduction of the maximum commercial efficiencies—of which there are several—and the solution of many interesting as well as of the essential problems designated by the writer, respectively, as the "designer's problems" and the "owner's problems."*

It is easy, however, to see that if the vertical scale of our diagrams were, as it might perfectly well be made, one of dollars instead of weight of steam, we might superpose upon the series of curves, constituting each, another, which should represent the varying costs of power external to the engine and the boiler plant, those costs which measure the annual value of capital invested and expenses incurred, apart from the internal costs of production of the power; such as, for example, in the former class, the interest on costs of engine, boiler, buildings, etc., and on the same scale which would measure the costs of the steam-supply already treated of. Referring to the first set of curves, assume the next to the upper line to represent these "internal" costs, and the upper curve to measure the "external" expenses, it is here seen that, as is the known fact, the latter being an increasing relative magnitude, the departure of the pair of curves from each other with increasing expansion, indicates that these new considerations dictate still further restriction of the ratio of expansion and still further narrow the range of nearly constant economy. As is elsewhere shown by the writer, this restriction is often more effective than even the enormous influence of internal wastes has been seen to prove. Where the designer seeks to ascertain what adjustment will give him the best work in proportioning an engine of either class to perform a specified amount of work, he often finds it necessary to adopt a ratio of expansion not exceeding two-thirds that dictated by the solution of the problem which it is the principal purpose of this paper to study; and when he again endeavors to ascertain to what power his client may drive

* Manual, vol. i, chap. vii; vol. ii, chap. viii.

up engine and boiler to obtain highest pecuniary returns from a "plant" already established and adapted to a specified original power—it being found that more power may be usefully employed or sold—he again finds that he may profitably restrict the ratio of expansion by perhaps another twenty-five per cent., and obtain large or at least fair profits on the new investment, notwithstanding the facts that the power added costs him more per unit than the original amount supplied by an engine precisely adapted to that rating, and that the new total power might be still more profitably produced by a new plant of proper rating and adjustment.

NEW CELLULOSE DERIVATIVES.*

By Clayton Beadle.

Nearly two years ago, my colleagues, Messrs. C. F. Cross and E. J. Bevan, and I, when working on the behavior of "mercerized" cellulose towards various reagents, discovered a new class of soluble cellulose derivatives. The ultimate products obtained from these promised to be of so much value and interest that we followed the work up with the greatest possible speed, one of us devoting his whole time to the prosecution of this work. It has resulted in the production of a large range of products, which we have every reason to believe are of great value. Mr. Arthur D. Little has been connected with us in working out the various developments over here. The results obtained by him, we believe, have largely added to the value and scope of our process. We published a brief account (*Chem. Soc. J.*, 1893, 837) of our early work on these compounds and indicated their probable line of developments. (*Soc. Chem. Ind. J.*, June 30, 1893.) After nine months' further work we are encouraged in the belief that the predictions we then made are on the eve of fulfilment.

*Read at the stated meeting of the Franklin Institute, April 17, 1894.

"MERCERIZED" CELLULOSE.

The action of strong solutions of caustic soda upon cellulose has been the subject of study for many years; but the susceptibility of cellulose to interact when so treated has only recently claimed attention. When cellulose (*e. g.*, cotton-wool) is treated with a solution of caustic soda containing fifteen per cent. NaOH the fibres are seen under the microscope to swell up and increase enormously in diameter, undergoing all sorts of contortions and twistings. The characteristic markings of the fibres are very much intensified, which affords a means of identification. The cell-wall absorbs within itself a considerable quantity of the solution. When this mass is washed with water, the soda is entirely removed. If pure cellulose be used, the weight obtained is somewhat greater than that of the cellulose taken. This effect has long been known as "mercerization."

Mercer, the first to study this, believed it to be due to a combination between the alkali and the cellulose in the ratio of $C_{12}H_{20}O_{10}$: 2 NaOH. On repeated treatment with alcohol, Gladstone has shown that the cellulose retains the soda in the ratio $C_{12}H_{20}O_{10}$: NaOH. The question whether "mercerization" is the result of a chemical union between the cellulose and soda, or the absorption of the soda, by the cellulose, resulting in the hydration and gelatinization of the latter, to form a colloid modification, must be left at present unanswered. The soda solution entering *en masse* into the cell-wall, and its easy removal by washing, would lead us to the latter conclusion; but for various reasons which we shall see hereafter it would appear that some sort of a union between the soda and cellulose takes place. Mercerized cellulose when washed and dried is found to correspond with the formula $C_{12}H_{20}O_{10}$, H_2O. The hygroscopic moisture is found to have increased from 6·5 per cent. (the normal figure for cotton-cellulose) to ten per cent. In common with most cellulose-hydrates it gives the starch reaction with iodine. This is beautifully demonstrated by placing drops of caustic soda solution of different strengths on Swedish filter-paper; after a few minutes,

washing the same until free from soda, it is dipped into iodine solution. The portion treated with caustic soda will be turned deep blue if the soda is up to "mercerizing strength." If the soda used is below this strength, a circular fringe of blue will be developed on the edge of the spot, where the water has evaporated and so concentrated the soda. This test gives us a means of determining whether the right "degree of mercerization" has been reached.

CELLULOSE-BENZOATES.

About three years ago we began to study the reactions of cellulose in presence of strong alkaline solution and obtained cellulose-benzoates by shaking with benzoyl-chloride. The yields and analyses showed variations between the di- and tetra-benzoate according to conditions of working. The yield of benzoate is limited, as might be supposed, by the "degree of mercerization." By dissolving certain hydrated modifications of cellulose in caustic soda, products of a uniform composition were obtained giving a higher yield of benzoate (*vide supra*). The activity of cellulose in this direction led us to study its behavior in regard to the vapor of carbon bisulphide.

CELLULOSE THIOSULPHOCARBONATES.

We found that when so-called "alkali-cellulose" is treated with carbon bisulphide vapor, at the end of three hours the mass will have changed to a deep golden yellow. This, when treated with water, swells up to a gelatinous mass and finally dissolves, forming a very viscous solution, about the color of treacle. The reaction that takes place may be expressed as follows:

$$\underset{\text{Alkali-Cellulose.}}{X.ONa} + CS_2 = \underset{\text{Cellulose Xanthate.}}{CS\begin{matrix}OX\\SNa\end{matrix}}$$

where X represents the reacting unit of cellulose. We have then cellulose-xanthate formed, which is soluble in water, with the formation of the solutions as above described.

COAGULATION.

This solution lasts only for a limited time. In a few days it is found to have set to a solid coagulum which is no longer soluble in water. The action which takes place is simply a reversal of the above, or a dissociation of the xanthate, which is readily brought about in presence of water.

$$\underset{\text{Cellulose Xanthate.}}{CS\begin{matrix}OX\\SNa\end{matrix}} + H_2O = \underset{\text{Cellulose.}}{CS_2} + X.OH + NaOH$$

The tendency of the solution to coagulate is conditioned by the amount of water present. Dilution, as might well be supposed, has been found to favor dissociation. The life of the solution is then greatest when the minimum quantity of water is used to bring the xanthate into solution. The color of the solution is chiefly due to the presence of thiocarbonate of soda, which is formed from some of the CS_2 and NaOH splitting off by gradual dissociation.

PROPERTIES OF THE SOLUTION.

Sulphuric and most mineral acids immediately precipitate the cellulose with the evolution of sulphuretted hydrogen. Acetic and many weak organic acids evolve sulphuretted hydrogen without precipitation of cellulose, the solution becoming nearly white and colorless, but much more liable to rapid coagulation. Bisulphite of soda or sulphurous acid decolorizes the solution without the evolution of sulphuretted hydrogen if carefully added. Zinc sulphate or chloride precipitates the zinc salt in horny flakes, which can be washed and easily redissolved in weak soda. Alcohol or brine precipitates the cellulose as thiocarbonate, which can be washed free from by-products and dissolved in water.

VISCOSITY OF SOLUTION.

This solution is very viscous, and very readily undergoes coagulation. The viscosity of the crude solution depends upon many conditions. It is possible to prepare two solutions from the same cellulose, one containing five per cent. and the other twenty per cent. of the same viscosity. If

the cellulose has been treated with caustic soda some weeks before treatment with CS_2, the viscosity of the solution is very much reduced. Raising the temperature of the alkali-cellulose has the same effect. A solution of greatest viscosity is got by treating with CS_2 immediately after mercerizing. This gives us, when cotton is used in a seven per cent. solution, a viscosity equal to glycerine, measured by rate of flow.

SPECIFIC GRAVITY OF SOLUTION.

The determination of the specific gravity of solutions of various strengths is not very satisfactory, but it clearly indicates that the specific gravity decreases with decreased viscosity, due to increased age of alkali-cellulose.

EFFECT OF TEMPERATURE.

Increased temperature shortens the life of the solution by inducing coagulation. A solution that would last forty days at 35° F. would coagulate in twenty-five days at 47° F., or in six days at 65° F. When a solution is spread on the surface of glass and exposed to a temperature of about 250° F. the coagulation takes only a few minutes. This, when washed free from by-products, comes off the surface as a transparent film.

EFFECT OF MASS.

Mass has a great influence on coagulation; a small sample of thirty grams coagulates much sooner than a 400 pound lot of the same solution when both are kept at the same temperature.

AIR AND CARBONIC ACID.

Coagulation is induced by exposure to the air, probably due to the presence of carbonic acid, which is found to aid dissociation of the cellulose thiocarbonate, by forming sodium carbonate and liberating CS_2.

PROPERTIES OF COAGULUM.

A solution when once coagulated, although it retains the water required for its solution, is no longer soluble. If a coagulum contains much under ten per cent. of cellulose

it will contract on itself, retaining the form in which it was cast and separating from the water and soluble by-products until it contains about ten per cent. of cellulose and ninety per cent. of water. On the other hand, if the coagulum contains a high percentage of cellulose it will expand and take up water. This coagulum will not dehydrate by treatment with alcohol. At this point it remains in a state of equilibrium so long as it is kept immersed in water. When the washed coagulum is taken out of the water and placed in air, by a gradual process of integration, the mass gradually contracts on itself until the whole of the water is eliminated. The resulting material is a hard, compact, horny substance, having a specific gravity of 1·5.

DECOLORIZED ACETIC ACID SOLUTION.

The crude thiocarbonate solution, when decolorized by the addition of suitable reagents, shows some marked peculiarities. When acetic acid is added, sufficient to render the solution just acid, on standing for some time the solution will have increased in viscosity and developed a marked alkaline reaction. The acetic acid decomposes the sodium thiocarbonate present in the solution, and, as dissociation proceeds, CS_2 is given off and caustic soda formed. If a non-viscous solution has been used, the viscous form can be induced by this method. The solutions coagulate a few hours after the addition of the acids unless kept very cool, and are more stable in dilute than in strong solution. A fresh coagulum from a strong solution can be rendered soluble by the addition of water and agitation, and the life can be extended for a considerable time by adding successive quantities of water at regular intervals and agitating. Alum may be used in place of acetic acid.

EFFECT OF SULPHUROUS ACID ON SOLUTION.

When sulphurous acid solution or sodium bisulphite is used in place of the above, the behavior is somewhat different. The sulphur compounds are, for the most part, converted into thiosulphate, and we have a more permanent solution. The influence of mass is here very much marked.

On placing the solution in tubes of different diameters, the smallest coagulates first, and so on, in order of diameter. The life of the solution is about thirty hours in small quantities, but it can be kept for six days in large quantities at the same temperature. It is more stable in dilute solution and the fresh coagulum is readily dissolved by ammonia.

PRODUCTS PURIFIED BY ALCOHOL OR BRINE.

The product got by purification with alcohol or brine is found on analysis to contain less sulphur and soda than the crude material, and by repeated treatment these may be got down to one-tenth their former quantity, but are found to bear about the same ratio to each other. As the S and Na_2O diminish, the solutions are found to be more viscous and less stable. It appears that the reacting unit of cellulose is not constant, and that the molecule may be at least $4(C_{12}H_{20}O_{10})$. The fact that two parts of cellulose in 1,000 parts of water, as a decolorized solution, will coagulate without change of volume, leads us to believe that the molecular weight of this cellulose is very high.

BENZOYL-CHLORIDE REACTION.

When a crude solution is treated with benzoyl-chloride, the cellulose is eliminated as a cellulose-benzoate. In view of this fact, we may be right in ascribing the following formula to the compound:

$$CS\begin{cases} OX.ONa \\ SNa \end{cases}$$

X representing a cellulose residue of variable molecular weight and reacting as an alkali cellulose.

COMMERCIAL PRODUCTION.

In preparing large quantities of this cellulose compound, we take a moist, disintegrated cellulose and incorporate it with strong caustic soda solution by agitation under considerable pressure. The cellulose, when acted upon by the soda, swells up and absorbs all the solution, becoming flaky. This is passed through a sieve in order that it may be of uniform density and occupy as much bulk as possible.

This process takes about thirty minutes, and one hundred and fifty pounds of mercerized product is obtained at each mixing. One cubic foot of the material ready for treatment with the CS_2 weighs about fifteen pounds. This is brought in contact with CS_2 vapor when the mass has been carefully raised to 80° F. and kept in agitation. The reaction develops enough heat to raise the temperature to 105° F., when at the end of one hour the reaction is complete. The material still retains its former structure, but has changed in color to a golden yellow. It is discharged into, and carefully mixed with, its own volume of water. In seven hours the mass has become a homogeneous stiff dough. To obtain a clear solution from this, it is passed, together with its own weight of water, through a centrifugal pump, and to free it from mechanical impurities it is passed under pressure through a filtering medium. The amount of caustic soda required is expressed in its simplest terms by the ratio $C_6H_{10}O_5$: 2 NaOH. The proportion of CS_2 used is expressed by the ratio CS_2: 2 NaOH.

The most favorable conditions for the interaction are:

$$C_{12}H_{20}O_{10}: 2\,Na_2O: 2\,CS_2: 35\,H_2O.$$

THE PRODUCTION OF CONTINUOUS FILMS.

When dehydrating agents, such as brine or alcohol, act on the cellulose thiocarbonate solution, the effect produced is dependent upon the constitution of the solution. Thus, if a fresh solution is used and brine added, the flocculent precipitate obtained is entirely redissolved in water. If the solution has been made some days and approaching the point of coagulation, the precipitate so formed is during precipitation converted into insoluble cellulose. If some of this solution is spread as a varnish on a glass plate, and immersed in brine, the cellulose can in a few seconds be stripped off the surface in the form of a film. We endeavored to take advantage of this for the production of continuous films, and after erecting six machines, each of which was a step in advance of the last, we devised a machine which produces and reels a film in a continuous

web. The thick solution, which has been kept till on the point of coagulation, is spread on the surface of a revolving cylinder half immersed in a bath of brine. The solution is spread by means of an adjustable doctor, attached to side deckels which regulate the width of the film required. The film as it leaves the brine is stripped from the cylinder and passed through a series of vats for washing, decoloring, dyeing and finishing. It can be dried by passage over steam cylinders and reeled. The film when in the web, before passing on to the drying cylinders, can be grained or stamped by rolls carrying designs in imitation of any surface. Cellulose films prepared by this method have an affinity for many aniline colors not shared by any other form of cellulose. Its power of absorption of various substances when in the half-finished state enables us to give to the finished product a large range of properties.

It becomes dyed so readily with some aniline colors without a mordant, that the operation can be done in the web as it passes over the machine. When dried and finished it becomes resistant and loses considerably its chemical activity.

COMMERCIAL PRODUCTION OF THICK FILMS.

(1) From crude coagulum. In order to prepare thicker films the solid coagulum is cut up into pieces of any desired thickness. These are washed to free them from by-products, and treated for some time under pressure, and calendered. By this means we are able to get a large range of products. Calendering has a marvellous effect on the films, if they are not thoroughly dehydrated. The material of the film flows under great pressure, increasing the area and decreasing the thickness of the film, and the annealing it gets very much improves its texture and strength. We have recently found it possible to forego the process of washing out the by-products, giving us films sufficiently pure for some purpose, by the following process:

(2) From decolorized coagulum. To the crude thiocarbonate solution is added a weak solution of sulphurous acid, which has the effect of decolorizing the by-products

by converting them for the most part into sodium thiosulphate. The coagulum formed from this is a semi-opaque neutral jelly. This is cut up into pieces of the size required, and each piece is submitted to a process of annealing under pressure which results in the dehydration and separation of the cellulose from the by-products. It has lately been found possible to pulverize the solid decolorized coagulum and cause it to go together into compact sheets under pressure; also to force several sheets together into one solid compact sheet. We had failed with all other mixtures to obtain a pulverized substance that would go together under pressure, and had given it up thinking it could not be accomplished, when the above mixture was formed to answer. It is very difficult to explain this peculiar behavior of a cellulose coagulum, and why the various mixtures should behave so differently. We recognized that we are dealing with a compound in a state of very unstable molecular equilibrium and consequently very susceptible to all sorts of outside influences. The effect of pressure in promoting chemical change has recently been recognized. We think that we have here a marked instance of what pressure will do in effecting a molecular change. By changing the modes of attack on this coagulum various products are obtained, differing widely among themselves in their general properties. We have found it possible to stamp boxes direct from the coagulum, embossing and dehydrating them in one operation.

Films may also be produced by taking a continuous veneer from a revolving cylinder of the dehydrated substance.

INERTNESS OF THE DEHYDRATED PRODUCT.

This is well exemplified in its application to woven fabrics. Cotton and linen goods behave very differently in regard to their affinity for, and power of fixing, these cellulose derivatives. When gray linen is passed through a weak solution of cellulose thiocarbonate it is easily fixed by the film. It appears to penetrate the cell-wall and build itself up in the fibre. The cellulose so fixed is not removed

by the various chemical treatments the cloth afterwards receives. The character of the solution used has a great effect on the finish of the cloth. It is possible to obtain a very marked difference in the feel by the addition of only two per cent., or to add to the cloth as much as twenty-five per cent. without making any marked difference. In all cases the cellulose derivative shows itself less acted upon by chemical treatment than the fibre of the cloth.

PROPERTIES AND CONSTITUTION.

Its inertness is shown also in its behavior with various reagents. Where it reacts it does so in a different way from that of cotton and linen cellulose. Its carbon percentage is somewhat lower and its weight is somewhat greater than the cotton cellulose from which it is prepared. The original molecule appears to have undergone hydration in the ratio $2C_{12}H_{20}O_{10}$, H_2O. The hygroscopic moisture varies from ten per cent. to fifteen per cent. according to the method used for its production. It is turned blue by iodine solution.

HYDRATION AND CONSTITUTION OF CELLULOSE.

It seems probable that in "mercerization" some of the OH groups are brought into play, rendering the molecule susceptible of attack by the carbon bisulphide; also that the OH groups play an important part in the molecular hydration. At the moment they are released by the dissociation of the thiocarbonate, the water present enters into a loose union with these groups, resulting in the formation of a coagulum which easily undergoes dehydration.

In a series of nitro-celluloses we prepared from cotton, of varying degrees of nitration, we found that the amount of moisture retained on exposure to air varied inversely as the yield. The moisture retained, then, varied directly as the OH groups left unsaturated. This led us to the conclusion that the moisture is some function of the OH groups. If, then, as we have reason to believe, in the formation of these cellulose derivatives certain other OH groups are brought into play, we should expect to find an increased attraction for water as above noted.

APPENDIX.

INDUSTRIAL APPLICATIONS OF CELLULOSE THIOCARBONATES AND PRODUCTS DERIVED THEREFROM.

By Arthur D. Little.

It was my good fortune to have the brilliant discoveries of my friends, Messrs. Cross, Bevan and Beadle, of London, communicated to me very shortly after their inception, and since then my time has been largely devoted to working out certain of the more obvious commercial applications of the cellulose thiocarbonate and the modified form of cellulose recovered through its decomposition.

Although in the early stages of the work numerous practical difficulties were naturally encountered, the development is at the present time going forward so rapidly that I cannot but feel that ultimately these discoveries will rank with that of Goodyear in the range and importance of their applications. Many fields in which these products will undoubtedly find place have already been entered upon, while almost daily new ones present themselves. Although the samples which we are able to show you to-night illustrate such diverse products, as thick, viscous solutions which replace glue; dense, hard masses which resemble ebonite; films so thin as to be almost intangible: artificial leather, floor tiles and boiler coverings—they are to be regarded only as the first outcroppings which show the general trend of the vein.

At the present time the various industrial applications of these materials, which have been sufficiently developed to permit the production of samples, may be conveniently grouped into six classes as follows: Applications of

(1) The crude solution.
(2) Dense cellulose in the mass.
(3) Films and sheets.
(4) Films and sheets formed on cloth backing.
(5) Porous cellulose.

(6) Various admixtures of cellulose and foreign substances, as untreated fibre or mineral matter.

In the production of almost all the samples here shown, the raw material used has been cellulose in the form known to paper-makers as soda fibre made from poplar wood; but as already pointed out by Mr. Beadle, any other cheap or convenient form of cellulose is equally available.

Taking up now in the order indicated above the different industrial applications to which these new products have already lent themselves, we have to consider:

(1) THE APPLICATIONS OF THE CRUDE SOLUTION.

(*a*) *Substitute for Glue.*—The viscosity and tenacity of the solution in water of the cellulose thiocarbonates, and the fact that the compounds upon drying and standing suffer spontaneous decomposition with recovery of the cellulose as an insoluble film, early suggested the use of the solution as a substitute for one of glue. A solution containing five per cent. of cellulose is much more viscous than a hot solution containing fifty per cent. of glue, and a ten per cent. solution is, under ordinary conditions, as heavy as can be worked to any advantage.

A one per cent. solution decolorized with sulphurous acid has been used in the commercial way for bill-posting, book-binding and the manufacture of three- and four-ply straw boards. No attempt has been made to wash out the salts, and in view of this fact it is noteworthy that there is an entire absence of odor in the finished product. The solution has been used in place of glue in binding a large number of books of all grades, from the cheapest to the most expensive. It will be noted upon inspection of the samples that all these books open perfectly flat at any page without straining or cracking the binding. No extended experiments have as yet been made looking to the use of this glue substitute in carpentry, but two pieces of maple, cemented with a ten per cent. solution on a joint of one inch area, have required a strain of over 500 pounds to separate them. This compares favorably with the best glue,

while in cost there is a large balance in favor of the cellulose solution. The latter has the further advantage of being comparatively little affected by a very moist atmosphere.

(*b*) *Cloth Sizing.*—A large field of use for the decolorized solution is found in the treatment of cotton and linen cloth for the purpose of securing a permanent stiffening or sizing, which is of special value in case of such goods as would ordinarily be starched. The cloth is passed through the decolorized solution, the excess squeezed out by rollers, the cloth then dried and afterwards washed and bleached in the usual manner. By this treatment the threads and fibres are more or less bound and held together by an excessively thin film of cellulose and any degree of sizing or stiffening may be obtained. Starch, clay and other fillers may be mixed with the solution and are then carried into the body of the fabric and made a part of it. Cloth thus sized or loaded becomes soft and flexible in water so that it may be washed without difficulty but again becomes stiff when ironed. It is expected that such cloth will find a use in the manufacture of collars and cuffs, table-cloths, shirt-bosoms, muslins, etc.

(*c*) *Vehicle for Pigment Printing.*—An extension of the above application is found in our new method of pigment printing, which consists in mixing the pigment with the decolorized cellulose solution, then printing upon cloth in the usual manner, then drying and finally washing. The drying decomposes the cellulose compound and causes the modified cellulose to adhere to the fibres, while at the same time carrying with it and fixing upon them the pigments with which it has been mixed. The pigments are thus firmly held within the substance of the cloth.

(*d*) *Paper Sizing.*—The addition of alum to the very dilute solution of the cellulose thiocarbonate determines the precipitation of the cellulose in the amorphous flocculent condition. It thus becomes possible to precipitate the cellulose among the fibres in a paper engine after the ordinary manner of engine sizing and the precipitated cellulose not only sizes the paper but brings together and assists in the reten-

tion of the fine particles of clay or other filler which would otherwise be in large part lost.

(2) DENSE CELLULOSE IN THE MASS.

This may be formed by allowing the solution to revert or decompose spontaneously with separation of the cellulose as a jelly. The by-products of the decomposition are removed by washing and the cellulose then dries down to a dense mass of specific gravity 1·53. It has much the appearance of ebonite, takes a high polish and may be easily grained or colored in the mass. It is quite homogeneous and may be worked in any direction. It has a field for use as insulating material and in the manufacture of buttons, tool handles, small articles and turned goods generally.

(3) FILMS AND SHEETS.

These may be made either in the continuous way, as pointed out by Mr. Beadle, or by pouring the solution upon a glass plate with deckel edges to control the thickness of the film or sheet, and then drying the solution down and decomposing the compound, preferably by dry heat or steam, and afterward washing out the soluble inorganic by-products. In this condition the sheets take colors very readily, and with proper care in the treatment may be made nearly as clear as glass, as will appear upon inspection of some of the samples submitted. Among the uses to which the thinnest of these films have been already put may be named the glazing of binders' board, the production of photographic films, facing blotting paper and the like. Specially lustrous and durable glazed papers are prepared by rolling on to the paper one of these thin films. If the paper is of the proper tint, a very close imitation of vellum is produced for use in book-binding.

The applications of the heavier sheets ranging from $\frac{10}{1000}$ to $\frac{30}{1000}$ or more of an inch in thickness are especially numerous. They may be stamped into small wares like plates, trays, boxes, brush-backs, shoe-counters, inner soles, embossed signs, etc., or the sheets may be printed upon and

stamped in almost any manner desired. Attractive covers for small books and pamphlets have been made.

(4) FILMS AND SHEETS ON CLOTH.

These are either formed directly upon the cloth or by rolling the wet film on to the cloth. Cloth faced in either way with the thinnest films is well adapted for curtain-cloth, book-binding and many other special uses. Cloth with a facing from $\frac{1}{1000}$ to $\frac{3}{1000}$ inch in thickness is valuable for many large uses. It may be caused to resemble morocco leather very closely and takes all the fine impression of the grain under a proper roll or die. It is especially well adapted to upholstery work, embossed hangings and interior decorations. The thicker sheets have proved themselves a handsome and durable floor covering.

(5) POROUS CELLULOSE.

By working the solution in such manner that the recovered cellulose has an open or porous structure, a new product of much beauty is obtained, which is especially adapted for fancy printing, embossed hangings, book-covers, fancy boxes, signs and small articles. It has been proposed to utilize this form of cellulose as a substitute for sponges, and there is no doubt that the structure of the sponge can be reproduced.

(6) MIXTURES OF CELLULOSE AND FOREIGN SUBSTANCES.

The solution lends itself very readily to admixture with such materials as ground wood, various fibres, clay and other mineral matter, and in each case the resulting mixture of recovered cellulose and the foreign ingredient possesses some novel and useful property. In this way we have prepared floor coverings which are either flexible like oil cloth or linoleum, or hard and rigid like tiles. Various forms of insulating material have been made, together with trunk boards, embossed panels, emery wheels and many other special articles.

The above list by no means completes the number of applications which we either have in mind or in the

partially developed state, but will suffice to indicate some of the points at which these new compounds may fairly be expected to touch the arts and to justify to some extent the high estimate which I placed upon the importance of these discoveries to the industrial world. Their value and interest from the scientific standpoint have already been widely recognized.

THE HEATING AND VENTILATION OF LARGE BUILDINGS.*

BY ALFRED R. WOLFF, M.E.

[*Concluded from p. 50.*]

It will be noted that these temperature stipulations vary from American practice in the following particulars:

(1) Our calculations, in this vicinity, are based, in general, on an external temperature of 0° F.

(2) We figure on heating our corridors, staircase halls, etc., to from 65° to 68° F.

(3) 70° F. is the desired temperature in stores and dwellings, though 68° F. appears to many of us pleasanter.

As a rule, Germans are disagreeably struck, on their visits to this country, with the higher temperatures of our homes and offices.

Presently a practical illustration of the method of using the coëfficients and diagram of heat transmission will be given; but, inasmuch as the same example can also serve the purposes of showing the method of determining the amount of air required for ventilation, and the amount of heat and of radiating surface to be provided to meet all conditions, it will be well to first call your attention to a few other facts in relation to heating and ventilation, which enter the problem.

The external air contains four parts of carbonic acid in

* A Lecture delivered before the Franklin Institute.

10,000, and a room is considered properly ventilated when the proportion of carbonic acid present does not rise to above six, possibly eight parts in 10,000. It can readily be shown that to secure the standard of six parts in 10,000 means the addition of 3,000 cubic feet of fresh air per hour for each person in the room; to attain seven parts, the addition of 2,000 cubic feet; eight parts, the addition of 1,500 cubic feet. This air may have to be heated in the winter months, from zero degrees F. to, say, 68° F., and at times higher, if it is to be the means of taking care, in addition, of the heat transmission from the room.

Furthermore, it may be well to point out that the value of radiating surfaces is about as follows:

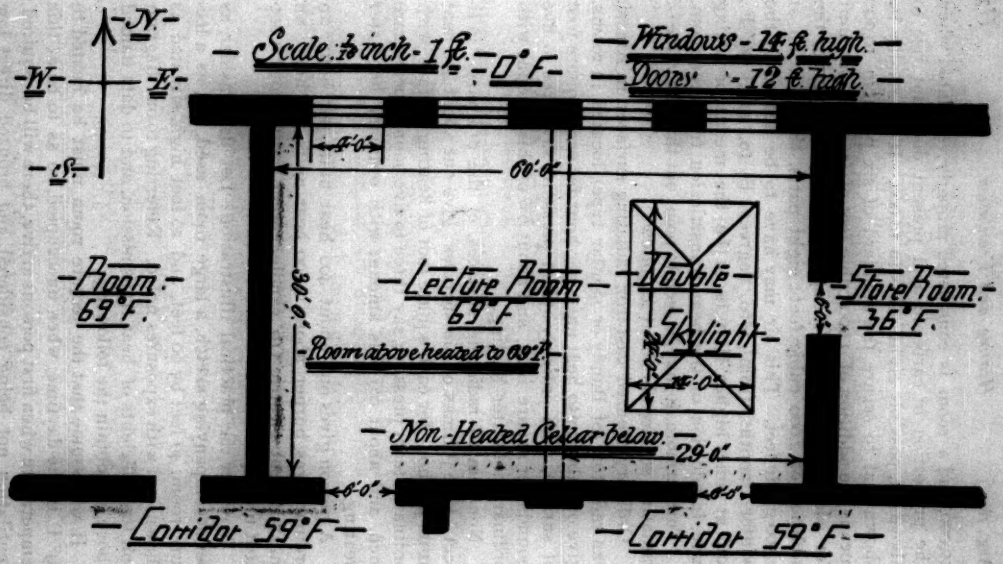
Ordinary bronzed cast-iron radiating surfaces, in American radiators (of Bundy or similar type), located in rooms, give out about 250 heat units per hour for each square foot of surface, with ordinary steam pressure, say three to five pounds per square inch, and about 0·6 of this amount with ordinary hot-water heating.

Non-painted radiating surfaces, of the ordinary "indirect" type (Climax or pin surfaces), give out about 400 heat units per hour for each square foot of heating surface, with ordinary steam pressure, say three to five pounds per square inch, and about 0·6 this amount with ordinary hot-water heating.

A person gives out about 400 heat units per hour; an ordinary gas burner about 4,800 heat units per hour; an incandescent electric (16 candle-power) light about 1,600 heat units per hour.

Now, for the practical illustration: Let us consider, as per accompanying sketch, a large room used, say, as a lecture room, 40 feet by 60 feet, and 20 feet high, situated as shown, and with exposures noted. Referring to our diagram and to coëfficients of heat transmission, and to data named above, we obtain the following:

If we assume that the lecture room must be heated to 69° F. in the daytime, when unoccupied, so as to be at this temperature when first persons arrive, there will be required, ventilation not being considered, and bronzed direct low


N.
W.
E.
S.
Scale: 1/10 inch - 1 ft. - 0° F.
Windows - 14 ft. high.
Doors - 12 ft. high.
6'-0"
60'-0"
30'-0"
Room 69° F.
Lecture Room 69° F.
Double Skylight
16'-0"
Store Room 36° F.
Room above heated to 69°
Non-Heated Cellar below.
29'-0"
6'-0"
6'-0"
Corridor 59° F.
Corridor 59° F.

pressure steam radiators in room being the heating media, about

$$\frac{113,550}{250} = \text{about } 455 \text{ square feet of radiating surface.}$$

(This gives a ratio of about 105 cubic feet of contents of room for each square foot of heating surface.)

If we assume that there are 160 persons in the lecture room, and we provide 2,500 cubic feet of fresh air per person per hour, we will supply $160 \times 2,500 = 400,000$ cubic feet of air per hour—

(*i. e.*, $\frac{400,000}{48,000}$ = over eight changes of contents of room per hour).

To heat this air from 0° F. to 69° F. will require $400,000 \times 0{\cdot}0189 \times 69 = 521,640$ thermal units per hour ($0{\cdot}0189$ being the product of a weight of a cubic foot by the specific heat of air). Accordingly, there must be provided

$$\frac{521,640}{400} = 1,304$$

square feet of indirect surface, to heat the air required for ventilation in zero weather. If the room were to be warmed entirely indirectly, that is, by the air supplied to room (including the heat to be conveyed to cover loss by transmission through walls, etc.), there would have to be conveyed to the fresh air supply $521,640 + 113,550 = 635,190$ heat units. This would imply the provision of an amount of indirect heating surface of the "Climax" type of

$$\frac{635,190}{400} = 1,589$$

square feet, and the fresh air entering the room would have to be at a temperature of about 84° F., viz.:

$$69° + \frac{113,550}{400,000 \times 0{\cdot}0189} \text{ or } 69 + 15 = 84° \text{ F.}$$

TABLE SHOWING HEAT UNITS TRANSMITTED FROM (AND TO BE CONVEYED TO) ROOM ON ACCOUNT OF HEAT TRANSMISSION THROUGH WALLS, CEILING, FLOOR, WINDOWS, ETC.

No.	Room.	Cubic Contents (in Cubic Feet).	t (Fahrenheit Degrees.)	$t - t_1$ (Fahrenheit Degrees).	Kind of Transmitting Surface.	Thickness of Wall (in Inches).	Calculation of Area of Transmitting Surface.	Square Feet of Surface.	K	$K(t - t_1)$ Thermal Units.	Supplementary Allowances.
	Lecture room.	48,000	69	60	Outside wall.	36"	63 × 22 — 448	938	9	8,442	10%
			69	60	Four windows (single).		4 × 8 × 14	448	72	32,256	10%
			33	24	Inside wall (storeroom).	36"	42 × 22 — 72	852	4	3,408	
			33	24	Door.		6 × 12	72	19	1,368	
			10	1	Inside wall (corridor).	24"	45 × 22 — 72	918	2	1,836	
			10	1	Door.		6 × 12	72	5	360	
			10	1	Inside wall (corridor).	36"	17 × 22 — 72	302	1	302	
			10	1	Door.		6 × 12	72	5	360	
			69	60	Roof.		32 × 42 — 336	1,008	10	10,080	
			69	60	Double skylight.		14 × 24	336	43	14,448	
			33	24	Floor.		62 × 42	2,604	4	10,416	
										83,276	
					North outside wall, 10%,					844	
					North outside windows, 10%,					3,226	
										87,346	
					Exposed location and intermittent day or night use, 30%,					26,204	
					Total thermal units,					113,550	

The above calculations do not, however, take into account that 160 persons in the lecture hall give out 160 × 400 = 64,000 thermal units per hour; and that, say, 50 electric lights give out 50 × 1,600 = 80,000 thermal units per hour; or, say, 50 gas lights, 50 × 4,800 = 240,000 thermal units per hour. The presence of 160 people and the gas lighting would diminish considerably the amount of heat required. Practically, it appears that the heat generated by the presence of 160 people, 64,000 heat units, and by 50 electric lights, 80,000 heat units, a total of 144,000 heat units, more than covers the amount of heat transmitted through walls, etc. Moreover, that if the 50 gas lights give out 240,000 thermal units per hour, the air supplied for ventilation must enter considerably below 69° F., or the room will be heated to an unbearably high temperature. If 400,000 cubic feet of fresh air per hour are supplied, and 240,000 thermal units per hour generated by the gas must be abstracted, it means that the air must, under these conditions, enter

$$\frac{240{,}000}{400{,}000 \times .0189} =$$

about 32° less than 84°, or at about 52° F. Furthermore, the additional vitiation due to gas lighting would necessitate a much larger supply of fresh air than when the vitiation of the atmosphere by the people alone is considered, one gas light vitiating the air as much as five men. However, we need not consider these computations more in detail, our object being mainly to point out and illustrate the methods of analysis and calculation in such a case, and to show how readily the problems can be solved by the data herein given.

A few practical conclusions are at once apparent: That the amount of air required, and the temperature of the entering air, as well as the amount of heating surface to be called into play, will vary very greatly in the same room, not only with variations in external temperature, but with any given external temperature, according to the use, occupation, method of lighting, etc., of the room. Also, that the variations will often be so quick during a short period of use of room, especially in auditoriums, theatres, ballrooms, public dining-halls, etc., that it is important either to have automatic heat regulation, or a competent engineer, who constantly and closely watches the changes in temperature and modifies the operation of apparatus accordingly. Of course, a stable condition of audience, lighting, etc., once secured, the regulation is a comparatively simple matter (a fixed right condition of operation of apparatus then usually filling the need); but from the time of opening the hall until this stable condition is reached, conditions will vary so much that failure is sure to result with the otherwise best apparatus, unless it be designed to regulate its heat radiation, etc., automatically, to suit these varying conditions, or a most competent engineer, of good judgment, regulate the apparatus according to frequent thermometer readings or reports.

From the considerations already set forth, and others to be presented, it will readily be inferred that the almost general introduction of electric lighting with isolated generating plants in large buildings, has had a sensible effect on the solution of the heating and ventilating

problem. On account of the economy secured, it has practically conditioned the use of exhaust steam for heating. It is an interesting fact that the quantity of steam required for heating and ventilating large buildings, notably club houses, colleges, theatres, halls, etc., equals closely the amount used independently for their electric lighting. Since electric light engines convert only about ten to fifteen per cent. of the heat of the steam with which they are supplied into mechanical energy, eighty-five to ninety per cent. of the heat is retained in the exhaust steam, available and just sufficient, as a rule, to meet the heating and ventilating needs of the building. This means practically that a boiler capacity ample for the heating and ventilating will take care, in addition, of the electric lighting of a large building, or *vice versa*; and that, in the winter months, the electric lighting is secured at only a slightly increased fuel expense. It is this fact which makes it difficult for either city or district heating or electric lighting companies to supply steam or electricity, respectively, to large buildings. They cannot compete with the cheapness of generation of the composite system of electric lighting and exhaust steam heating of the isolated plant within the building. Of course, this composite system implies generally the additional wages of an extra fireman or engineer, but it can easily bear this additional expense, and still be decidedly on the winning side in competition with outside district companies. It is of importance to have the cylinder proportions of the electric light engines such that the desired power is developed with a back pressure as high as five pounds to the square inch; for, in American practice, such pressure may be required for heating in the coldest weather. This back pressure, if originally figured on, is neither detrimental nor uneconomical, and I have not been able to recognize any advantages in the vacuum systems, except where the engines or the piping were proportioned incorrectly at the outset, or where the installation of the electric lighting plant, and the use of exhaust steam for heating, were afterthoughts. In those cases, the vacuum systems frequently perform a useful service.

Another way in which the introduction of electric lighting has affected the heating and ventilating problem is, as above already referred to, that the electric lights give out less heat and vitiate the atmosphere less than gas. Besides, there are no volatile products of combustion—representing vitiation and heat—to be taken off as far as practicable at the points of generation; nor must flicker of light, on account of air currents, be guarded against. The fact that a single gas light vitiates the air as much as do five persons, and that the electric light causes no vitiation whatever, materially affects the quantity of fresh air to be supplied to keep the atmosphere within a room at a proper standard of purity. Again, the fact that besides not dealing with obnoxious gases, no flicker of flames must be considered in electric lighting, renders it possible, when so desired, to bring in the fresh-air supply at the top of a room (either by wall registers or through perforated suspended ceilings) and to exhaust at the bottom, a reversal of the ordinary process, and one impracticable when gas lighting is resorted to.

While in my judgment the main problem in the proper ventilation of large buildings is to secure an adequate supply to, and removal of air from, the separate rooms, I would like to call your attention to a distinct and important advantage obtained by having the air enter through perforated ceilings at the top of the rooms, and exhausting at the bottom. At night, in a crowded assembly, when the electric lights aglow are giving out some heat, even though it be considerably less than gas lights would evolve, it is frequently found in practice, as the calculations of our example have already indicated should be the case, that, even in very cold weather, to keep the air within the room at a temperature of 68° F., the entering fresh air must be at a temperature considerably lower than 68°. At the recent opening of the new concert hall of the Mendelssohn Glee Club building, a room with scarcely any outside exposure, and practically dependent on an artificial air supply by means of a blower, it was found necessary, even while supplying over 3,000 cubic feet of fresh air per hour for

each of the 1,000 persons in the audience, and with an external temperature of 40° F., to have as low a temperature as 52° F. for the entering air, to keep the hall at 68° F. Nor is this an unusual experience.

If the entire air supply enters by means of registers, or openings in or near the floor, it is very difficult, however large the openings, to obtain such a distribution and low velocity as will prevent the sensation of a cold draught when air is entering in large volume at a low temperature. It is a possibility, but usually it is impracticable structurally, to secure the required low velocity and uniform distribution. But if the air enters at the top, not only can a low velocity and uniform distribution be secured by means of large perforations in decorative designs of suspended ceilings, but a low velocity is of less importance, for the cooler air is heated in transit, and by the time it has reached the audience it has attained a temperature in the neighborhood of 68° F., and is no longer cooler than the air at exhaust where the people are congregated. If the hall is very high, it requires quite a powerful exhaust to ensure the air reaching the floor at such times as the entering air must be heated; but this is a detail readily solved in practice. In the main auditorium of the Carnegie Music Hall, with its seating capacity of over 3,000, the fresh, cooled or warmed air enters through perforations in the suspended ceiling, and travels with slow velocity a height of about eighty feet to exhaust openings in the floor risers, and an equable temperature is maintained under any external atmospheric conditions. In such a system it is specially important that the volume of air exhausted be less than the volume of fresh (warmed) air forced into the hall, so that the air within the room be under pressure; otherwise, external cold air will be drawn into the building through doors and windows, and may create objectionable draughts. But the desired conditions here briefly presented are readily attainable; and, especially in case of an enclosed room, the system of supply at ceiling and exhaust at floor level is the ideal one, when the room is lighted electrically, to secure pure air and moderate temperatures in crowded assemblies during the winter months.

In the summer time, many persons like to feel a decided current of cooled or cooler air, and thus it is often considered preferable to have the air enter at bottom and to exhaust at top of room. A reversible system may then be adopted to meet the conditions of comfort all year round.

In my own practice, when air enters and is exhausted through ducts in the walls, I have found it advantageous to have both top and bottom registers for each fresh-air flue, and top and bottom registers for each vent flue. In this way, the fresh air, when warmed, can enter at one and the same time through bottom and top register, with a corresponding desirable reduction in velocity, each flue having two outlets. When the air, in the winter months, on account of crowded assembly, must enter at a low temperature, the bottom register can be closed, and in the summer time, if a current of cold air is to be strongly perceptible, the top register can be closed. In general, when air enters through top registers, the exhaust should also be by means of the bottom registers of the vent ducts, and *vice versa*, and when air enters through both top and bottom registers, the exhaust should also be through top and bottom registers.

The selection of the special system of heating and ventilating to adopt in a particular building depends, of course, in addition to the considerations already set forth, and to similar ones of a physical and engineering nature, greatly on the structural possibilities; for, important as are the heating and ventilation, owners and architects are not as yet quite ready to sacrifice other useful and artistic features to the one which has been the topic of this lecture. The engineer, therefore, if he would not have the heating and ventilating needs neglected, should be quick to recognize the system to adopt which will insure success, and will, at the same time, not prove a nuisance to the specific architectural and artistic interests of the building. Frequently, such decision must be cast at a first inspection of the plans. Of course, there should be "give and take" in this matter on both sides, and the purely decorative and structural interests should occasionally yield a point too.

It is evident that the best result is achieved if the engineer who is to design the engineering equipment be consulted when the original architectural plans are drawn, and before these plans have crystallized into definite and unalterable shape; for thus, in harmony of co-operation, the best is accomplished by both the architect and the engineer, and the engineering equipment, including the heating and ventilation, proves satisfactory, without encroaching on the highest architectural, structural and artistic possibilities and success. In closing, it is a pleasure to record that at the present time some of the leading architects recognize the advantages of an early co-operation in these respects with the engineer.

ENGINEERING PRACTICE AND EDUCATION.

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[*Continued from p. 45.*]

In the preceding lectures, all the illustrations which have been used are commonly recognized as engineering works, though some are often classed as civil, and some as mechanical engineering. I have endeavored to show that the distinction is a purely artificial one; that the civil engineer who is to carry on responsible work, cannot get along without what is commonly called mechanical engineering; that the science of engineering is one, though very extensive in its range, and that the history of the development of engineering up to and in modern times is the history of the development of machinery, whereby we direct the great sources of power in Nature for the use and convenience of man. In this lecture, I propose to present to you a very brief view of the part that engineering work plays in what are commonly called the industries of the world. Of course, any presentation which I can make in an hour

must be very incomplete, and I shall choose only a few illustrations, and leave them to serve as examples of a much larger number.

And first, before taking up any manufactures, I ought to say a few words about mining.

I suppose that, in the popular mind, mining operations have generally been intimately connected first with geology, second with chemistry, and but slightly with engineering; but, if we stop to examine the actual condition of things, we shall find, I think, that, whereas there are cases where the man who has charge of a mine, or of a metallurgical works, needs to give his own attention primarily to metallurgical, to chemical, or even to geological questions, and where engineering questions are a secondary consideration, the cases are more frequent where much the larger part of his attention needs to be devoted to the engineering questions that arise in the work.

Geology serves to locate the mine, and to inform him what he may reasonably expect to find within the bowels of the earth, and what is the precise location of the deposits, so that he may know what excavations to make to reach them. It teaches him also the nature of the neighboring layers, and the difficulties he is liable to encounter in consequence of the characteristics of these materials; but all the exploration is largely completed before the mine is opened, or, at least, it is usually finished for any portion before the works are commenced on that portion, so that the amount of geological work to be done during the operation of the mine is generally not large.

Chemistry tells him the composition of his ores and of his product, and hence gives him the means of determining how to mix and how to treat them, but any one mine is dealing with one kind of ore, and any one metallurgical works is conducting a certain special kind of operations, and, therefore, the chemical work required in connection with them is limited to certain narrow lines. The result is that, after the works have been running for some time, the chemical work, while it requires careful attention, is, nevertheless, largely a matter of routine; to carry it out are

required men well drilled in this routine, and it is not necessary that they should be expert chemists, for, if a problem occasionally arises which is outside of the routine, and of sufficient consequence to warrant it, an expert chemist can be employed to solve it.

When we come to the case of metallurgical works, of course the man who is to manage them must have the necessary knowledge of metallurgy—of that kind, at any rate—or else he does not know his business, and he must devote whatever time and thought is necessary to all the metallurgical questions that arise which are not matters of routine, for those that are can be performed by men skilled in the special work, the manager only exercising enough supervision to see that these matters proceed correctly. When this is done, the problems that ought to engross the larger part of his time will depend upon the nature of the works. In some of them metallurgical problems will absorb more of his time than engineering, but in the greater number of such works the engineering problems will demand a larger part of his time and thought than the metallurgical, if he is to run the works with the best results.

Now, in the case of the engineering work, new problems are constantly to be solved, new emergencies are constantly to be met, for the mine must be kept running both economically and efficiently if the work is to be properly done; and if the works are large the engineering work assumes very large proportions. Some of it can be done by the manager personally, but a very large amount he must delegate to assistants, and these assistants must understand engineering.

In order to make plain how large an amount of such work has to be performed, I might say that in the case of a mine of any sort, unless it is very small, there is water that must be removed; hence, there must be machinery for pumping; the material mined must be lifted out of the mine, and the miners and various supplies must be carried in and out of it; hence, hoisting machinery of some sort is needed; rock drills must be used, and these are driven

by compressed air; hence, air compressors, and suitable engines to drive them; the men must be furnished with fresh air and the foul air must be removed; hence, some sort of ventilation must be provided. All this is necessary in any mine, besides timbering or walling the shafts and certain galleries. Then when the ore has been hoisted it must be broken up and prepared in various ways before it is ready for the furnace, and in many cases the works for preparing it—commonly called the mill—are not far from the mine.

Confining our attention first to the mine itself, we find, in regard to the pumping, all sorts of methods in operation, some very wasteful, and others varying in economy in every conceivable degree, according to the amount of engineering knowledge, and the judgment of the mine engineer. Thus, he may use direct-acting pumps at the bottom of the shaft, and at intervals along it, but the engineer knows that these are very wasteful of steam, and hence of coal; or he may bring to bear his engineering knowledge, and put in whatever will be most economical under the circumstances, be it a triple or a compound engine to do the pumping. The details of the arrangements of pumps and pump rods, and their connection to the engine, are all matters that must be attended to. Then, in regard to hoists, there is great room for choice, and a good opportunity for the engineer to exercise his talents. Probably the most instructive example apropos to this phase of our subject is afforded by the hoist now being put in the Calumet and Hecla mine. This machine is to lift ten tons of ore at the rate of sixty feet per second, through a height of 6,000 feet. The engine is triple-expansion, with cylinders 20½, 31¾ and 50 by 72-inch stroke.

At this mine many modern appliances have been introduced, among others three hoisting engines, which are triple-expansion, with cylinders 18, 27¾ and 48 by 90-inch stroke. In order not to interfere with the work of hoisting the ore, a separate engine is usually provided to run the man hoist, which may be the regular man engine, or may be a car drawn by another hoisting engine. Then comes

the choice of compressors and engines to run them, their erection and operation; then the means of ventilation, whether by natural draught or by an exhaust fan.

All this, of itself, if the mine is of any considerable magnitude, means the establishing of a large plant of machinery, and hence all the engineering work and all the engineering features necessarily involved in the erection and operation of such a plant, besides the engineering work that relates particularly to the special machinery in use and the special work to be accomplished by it. There must be, of course, a suitable boiler house and chimney, and suitable boilers must be erected and operated with whatever adjuncts, as economizers, etc., it is thought best to use, the conditions here being exactly the same as they are in the case of any boiler plant, and hence, engineering questions. Then the principle which directs the engineer to concentrate his power in one place, as far as possible, and hence to use one large and economical engine instead of several small and wasteful ones, applies here as it does to any power plant. How far this concentration can be carried must depend upon a consideration of the special conditions of the work; and all this involves, of course, a consideration of the arrangement of the works and of the system of power transmission. Of course, the arrangement of the power plant will probably be affected by the manner of getting the power from the engine to the pump rods or man engine rods, or rope drive, etc., that carry the power to the shaft.

In all these works, in the erection of the buildings, in putting up the machinery, etc., as well as in making suitable constructions to hold it, and in timbering or walling the mine, maintaining the works in serviceable condition, etc., questions of strength of materials are constantly coming up.

Then, again, the engineer must consider the means of handling the ore as it comes from the mine, and of transporting it to the place where it is next required. Then, if it is to go to the mill, it must be carried there, or, if it is to go to a distance, must be loaded into cars. Of course the

engineer will take advantage of the force of gravity whenever he can do so, for that costs comparatively little.

Next, as to the mill. Here the nature of the machinery will depend, of course, upon the particular kind of ore being treated.

We have first the ore dressing, and this involves the exercise of a very large amount of engineering. In certain cases the crushing is done by a stamp mill, in others by crushing machines or crushing rolls. Then come the arrangements for sorting the coarse from the fine, for separating the part which contains valuable material from that which does not, sometimes by gravity, sometimes by amalgamation, sometimes by magnetism, etc. Then, if the mine is large, the waste material must be removed, which is done by means of lifting or transporting apparatus, as, for example, the sand wheel.

Moreover, in any process of concentrating, a large amount of water will be needed, besides which it is also necessary for the boilers and for other purposes. Hence it becomes necessary to find a suitable water supply, and to set up the pumping engines required, etc.; in short, to establish a water supply, and finally, the waste water must be disposed of. Now, these engineering questions are everyday matters, and wastefulness or inefficiency here means expenditure with no return, hence all the coal that can be saved, all the labor that can be saved, all the saving that can be made by avoiding the doing of useless work, all the saving of unnecessary handling, will all show their influence in the dividends of the stockholders and in the successful operation of the mine just as truly as will the adoption of the proper treatment of the ore instead of an improper one. Of course, in any particular case, it becomes a question whether we will put in the best machinery, and thus economize in the running expenses, with, however, a larger first cost; or whether we will save on first cost at the expense of economy later on. Usually, if the owner lacks confidence in the amount of the ore in the mine, he will be wise to save on first cost. But if he knows that the mine will succeed, his best course is to put in the most economical

machinery, notwithstanding that it is more expensive at first.

Next in order come metallurgical works. Of course, the treatment of the materials by metallurgical processes which will produce the proper result is the primary purpose of the works; but these processes cannot be carried on without buildings, furnaces, steam or water plant, power transmitting machinery and apparatus, the erection and operation of all of which involve engineering questions which, if neglected by those who operate the works, are sure to result in disaster. As an example, suppose the owner of a blast furnace should insist on burning coal under his boilers instead of utilizing the waste heat from the furnace, this would simply be throwing away so much heat, and hence so much money. Now, when competition becomes sharp, the man who can make a saving in any way is the gainer; and if unsuitable or weak buildings, or unsuitable or weak machinery, or lack of economy in steam, are tolerated, or if care is not taken to save labor as far as possible, the neglect is sure to result in loss; and it is the fact that people are beginning to realize the truth of this statement that is causing the proprietors of such works to pay more and more attention to their engineering features, and to seek men who are familiar with the principles of engineering, instead of attempting to carry on the engineering portion of the work with the aid of men unfamiliar with these principles, and hence liable to make serious and costly mistakes.

Now, in regard to the metallurgical and chemical processes, there is always a certain portion at least of these that, after the works have been running some time, become largely matters of routine, varying only within certain narrow limits; and these, while they need careful attention and skill, can be delegated to a superintendent, whose business it is to attend to this part of the work.

There then remains that portion of the metallurgical and chemical work which is not reduced to a routine, and all the engineering work (which can never be reduced to a routine), to be attended to.

Now, the relative proportion of time and attention

required by each of these for its proper conduct, will depend upon the nature of the works, but it is my belief that in the greater number of cases, more time and attention is required for the engineering if the works are to be run economically and efficiently: but be this as it may, in no case can this branch of the work be neglected without loss.

My time is so limited that I shall only present for your consideration one illustration of a metallurgical works.

The discoveries and inventions that have furnished us the means of making cast iron, wrought iron and steel on a large scale, and cheaply, have had an enormous influence upon the industrial progress of the world.

In the early part of this century wrought iron was not used as a structural material to any such extent as it has been in recent times, and it was not until about the middle of the century that it began to come into common use for beams, for columns, for boilers, for bridges, and for many parts of machinery. But when once introduced, it became the great structural material of the age, and has held its sway ever since, until now, when steel is rapidly displacing it for many uses.

So long as steel could be made from wrought iron only, as by the crucible process, it was altogether too expensive a material to use in construction, but the introduction of the Bessemer process, by which it is made directly from cast iron, so cheapened it that steel rails at once came into use; and since that time the development of this process, and also of the open hearth or Siemens-Martin process, where a regenerative furnace is used, and where the steel is made from a mixture of pig iron and scrap or ore and other ingredients, have so far improved, that now our boilers are made of steel, and steel beams, steel ties, steel shapes, steel shafts, and steel for most pieces of machinery, which heretofore have been made of wrought iron, are fast coming into use.

Now steel works may, and very commonly do buy their pig iron from some blast furnace works, and proceed to melt it in a cupola, and then, if they have a Bessemer plant, to make it into steel, or, if an open-hearth plant, to put

it at once into the furnace. But at some of the larger works, both in America and abroad, they have a plant which includes the blast furnaces, and which, starting with the ore, makes it into cast iron, and then, without allowing the melted iron to cool, converts it into steel; then rolls it immediately into the finished form of rails and other commercial product. In other words, the iron is not allowed to grow cold from the time that the ore first enters the blast furnace until it has become a finished rail.

Such a plant as this is that of the Maryland Steel Co. These works have been quite recently built, and great care has been taken to introduce the most modern ideas and appliances throughout.

The ore used is foreign ore, brought to the works by water, and as it is unloaded from the boat it is loaded into cars having a hopper on the bottom, which can be opened to dump the load. There is a railroad track running up over a series of pockets or bins, and the loaded cars are run up on this track to the proper place and the ore is dumped into these pockets or bins. From the bottom of these bins shutes extend downwards nearly to the ground, and through these shutes the ore is delivered on the ground in such small quantities as may be required. The coal and other raw materials consumed by the works are treated in a similar manner, some of the bins being used for ore, some for coal and some for flux. The ore, the coal and the flux, in turn as they are required, are shovelled into small, narrow-gauge truck cars, which are run upon a platform scale and weighed, the amount on the truck being adjusted by adding or by taking off some of the load while the car is still on the scale. The truck is then run upon an elevator, and raised to the top of the blast furnace. There are two such elevators, side by side, one of which rises when the other descends, their weights balancing each other when they are not loaded.

There are four large blast furnaces. When one car, the bottom of which is so arranged that it can be opened to dump the materials, arrives at the top, it is run on a track to a point over the top of the furnace, but to one side of the

center; the next load being dumped on the other side of the center, insures an even distribution. Two trucks go up at once on an elevator, and there is room for both on one track over the furnace. The bottoms of the cars are opened, and the materials are dumped around the edges of a cone-shaped cover. Then, when the charge in the furnace has sunk low enough, as determined by sticking a long poker through a small hole in the cover, the cone is lifted, and the charge drops down. The lifting of these covers is accomplished by gearing and chains, which, of course, requires some power to operate.

The boiler plant is large, and contains a number of large sectional boilers. The waste gases from the blast furnaces pass out through a flue which starts below the cone already described, and then are conveyed to the boiler house, where the necessary flues and dampers are so arranged that, by manipulating the latter, the hot gases can be conducted under any one, or under several of the boilers, or sent directly into the stack. These boilers furnish steam for all the purposes for which steam is used, *i. e.*, for running the large compound vertical engines which produce the blast, for running the pumps and air compressors, etc. Water is circulated around the furnace to keep it from becoming too hot.

The furnace is tapped at the bottom, and the melted iron runs out, and, if they are making pig iron, which they can do, they would let it run into the usual trenches on the ground, known as the sow and pigs, or, if it is to be made into a rail before it cools, it is run from the furnace into a ladle, which, with its charge, is carried on a truck drawn by a little locomotive to the Bessemer plant. Here the charge is poured into a large chamber or reservoir, called a mixer, which thus contains a store of melted cast iron to be drawn from as needed.

Near the mixer are some small cupolas, where some pigs are melted. A charge is now drawn off into a ladle, this charge being often a mixture of metal drawn from the mixer and from the cupola. This ladleful of metal is now poured into a Bessemer converter while it is on its side. Then the

blast is turned on and it is then placed in the erect position, and at once we see flames shoot out of it. The flames at first burn off the silicon; when this is burned out, and the carbon begins to burn, the flame becomes white, with purple streaks; at this point some scrap is often thrown in if the temperature becomes too high. When, finally, the carbon is burnt out, the flame drops and then a ladle hanging on a hydraulic travelling crane is brought up near the converter, the latter is turned down, and the metal is poured into it, some spiegeleisen having been first added in the converter. The spiegeleisen is a cast iron having a variable but known quantity of manganese and carbon. The converter is now turned over, and the metal is poured into the ladle and carried by the hydraulic crane to a position over the ingot moulds, which are on trucks on the ground; and the melted steel is allowed to run into the ingot moulds through a hole in the bottom of the ladle. The trucks carrying the ingot moulds and ingots are drawn by a little locomotive to the rail mill, near the entrance of which there is an ingenious mechanism for stripping the moulds from the ingots. The ingot is then placed in what might be called a reheating furnace, *i. e.*, one in which heat is applied for the purpose of imparting to it an even temperature throughout. After this the ingot is taken by a hydraulic crane and deposited in a tilting box by means of which it is placed upon the apron of rollers which deliver it to the rolls; then it follows one rolling process after another till it is formed into a rail. Without stopping to discuss the arrangements here, it is plain that not only economy of heat and steam has been taken into consideration, but also economy of labor in handling, besides which a host of engineering problems have been worked out, and are constantly to be worked out. In connection with these works they have established an iron ship-building plant, and are adopting such arrangements as will make it quite extensive when completed, but I shall not describe or comment upon this.

Let us take as our next illustration a textile manufactory, and, as an example, a cotton mill. Here, if we follow

the successive steps of the process, we must receive the cotton, unload it, weigh it and store it, separating the different grades. Then, from the storehouse it is carried to the heaters, and, after the bags and hoops are taken off, it is beaten, then passes to the pickers, from there to the carding, then to the slubbing, then to the roving, then to the spinning, whether mule or ring spinning—or some to one, and some to the other—then to the spoolers and warpers. Then the warp goes to the slashers, where it is sized and dried, and then to the looms, where it is woven into cloth, after which it may be treated in various ways. Thus, it may be finished for the market by singeing or shearing, or it may be bleached, or dyed, or printed.

Now, in planning a mill, the first thing to be considered is a proper mill site.

In choosing a site the engineer must consider especially the ease and cost of transportation of raw materials and fuel to the mill, and of the finished product from the mill to the market. If it is near tidewater or near a railroad center it will be favorably situated on these accounts. Nearness to the market, and to the base of supplies, or a situation on a stream where there is an abundant water-power available for the mill, are advantages to be taken into consideration.

Now, when the site has been fixed upon, he must proceed to lay out his mill on paper, and in doing this he must first decide upon the kind of work the mill is to perform, and hence the kind of machinery that is to be used for each process, and the number of machines of each kind, their floor space, weight, etc., also the number of stories of the mill, and also what shall be its dimensions. These latter questions may be determined by the size and shape of the lot of land available, but considerations of light have to do with the determination of the proper width of the mill. He must then proceed to locate his machines on paper so that the processes shall follow each other in proper succession, and so that the material shall pass from one process to the next with as little handling as possible, and a saving in this regard is of very great importance.

When the machinery is all laid out he must arrange his

transmission, shafting, pulleys and belts, and decide upon the position for his engine house and boiler house, his belt tower, and his transmission system. Then he must arrange his machines, so as to give the necessary space between and around them for working, and the pulleys on the shafting for driving the machines, so that there shall be no interference.

Of course, the storehouse must be planned and its position relative to the picker house. When this is all done he can determine upon the size of the mill and the position of the walls.

Then he has to determine the probable amount of power required, and thus the size of the engines and boilers.

In all of these determinations he must allow for a reasonable amount of growth, and consider what changes would have to be made, and see that the mill is so built as to admit of them.

Then the engine and boiler house must be planned, the belt tower, and the walls and columns and floors and roof of the mill, and then also its foundation. Also proper regard must be had for protection from fire.

He must ascertain what is the foundation on which he has to build, and he is liable to find that it varies at different points, and that while under some parts the foundation is good, under others it is poor, and he may have to resort to any of the usual engineering expedients to build upon it. Then, of course, the dimensions of the walls, columns, floors, foundations, etc., must all be calculated so that they shall have the requisite strength and stiffness.

Then the work must be executed, and he must see that the materials delivered on the ground are good, and that the work is properly done in all its details.

In determining upon the necessary steam engines and boilers he must take into consideration all the uses for steam in the mill. Thus, there is the heating and possibly ventilating, and also the slashers that require steam, besides which more steam will be required if there is a bleachery or a dye works connected with the mill. According to circumstances we might decide upon one or another kind of engine.

Whatever system of heating and ventilating is adopted must be planned, and all the piping, fans, etc., must be put in and fitted.

Then there must be some source of water supply, capable of furnishing water for the boilers, for drinking, for sanitary purposes, and for a variety of other uses about the mill. Then the drainage must be attended to. After all is built and arranged and the mill is running, questions are always arising as to how certain things can be improved, questions of what oil to use for lubrication, also questions of improvements in the machinery, repairs, etc. And all this is besides the carrying out of the series of processes for which the mill was built and for which it exists. But these processes become, to a very considerable extent, routine matters, though they must be carefully watched and improvements and adaptations made when needed. The superintendents must watch them carefully and must be men skilled in their own departments, and the one who has charge of the mill must also concern himself with them, but his engineering work will usually be larger in amount than the work that he has to perform in direct connection with making the fabric.

[*To be continued.*]

A THEORY OF THE ACTUAL EARTH PRESSURE AND ITS APPLICATION TO FOUR PARTICULAR CASES.

By P. VEDEL, C.E., M. West. Soc. Eng.

The actual pressure of a body of earth is in most cases, or practically always, an unknown quantity. Only when a sliding plane is determined beforehand by any local peculiarities, such as a fissure in the ground or a stratum of soft material, may we form an approximate idea of what the actual pressure is, or of what it probably will be. The rational theory of earth pressure which is based upon the differential equations considers the state of limit-equilibrium where

all the particles are upon the point of sliding upon each other. It gives, even with this limitation, the solution only for a few special cases, inasmuch as the differential equation of second degree and second order to which it leads is not integrable in its general form. And in those special cases the solution is the same as the one given by the old theory which is based upon Coulomb's principle of the prism of maximum pressure and the assumption of plane sliding surfaces. This theory, considering the limit-equilibrium of the finite Coulomb's wedge instead of the infinitesimal parallelopiped of Cauchy, the coincidence of the results is remarkable.

To know the actual pressure of the earth it would be necessary to trace the minute history of the whole earth body. This historical element, which is usually neglected in theoretical treatises, is evidently of the utmost importance when the actual pressure is required. How the filling was done, the thickness and inclination of the different layers spread out, their subsequent consolidation, exposure to rain and frost and changes of temperature, rise and subsidence of water—these and other historical facts all contribute to determine the actual pressure.

For most practical purposes it is of little interest to know the actual earth pressure. What we want generally is the maximum possible pressure (active pressure) and the minimum possible resistance (passive pressure). If a wall will stand the maximum pressure which can come upon it, then we know it is strong enough. And if it can sustain certain forces applied upon it by the minimum counter-pressure of the earth in front of it, then—supposing its monolithic nature conserved—we are satisfied as to the stability of the structure. It is usual, and, in fact, nearly always sufficiently exact, to adopt the old theory laid down by Coulomb, and further developed and applied by Navier, Poncelet, Culmann, Rebhann, etc. The analytical expressions, first deduced by St. Guilhem, may be reduced to the following formulas for the limit pressures on a solid wall (given, somewhat modified, in Henket, Schols en Telders' Waterbouwkunde, 's-Gravenhage 1885):

$$\begin{cases} P = \frac{1}{2}\gamma \dfrac{H^2 + 2HH'}{\cos^2\varepsilon} \dfrac{\cos(\varepsilon - \omega)\cos(\varepsilon \mp \varphi)}{\cos(\varepsilon - \omega \pm \varphi \pm \varphi')} tg^2\left(45^\circ \mp \frac{\theta}{2}\right) \\ K = \frac{1}{3} H \dfrac{H + 3H'}{H + 2H'} \\ \text{where } H' = \dfrac{\rho}{\gamma} \dfrac{\cos\varepsilon}{\cos(\varepsilon - \omega)}, \sin^2\theta = \dfrac{\sin(\varphi \mp \omega)\sin(\varphi + \varphi')}{\cos(\varepsilon - \omega)\cos(\varepsilon \pm \varphi')} \end{cases} \quad (1)$$

Here P is the pressure on the wall, the maximum active or the minimum passive according as the upper or lower sign is everywhere taken, and K is the vertical distance of its point of application above the base of the back of the wall. Further, H is the total vertical height of the wall; γ the weight of a unit of volume of earth; ρ the load on a unit of the sloping surface of the earth; ω the angle of the slope at which the surface rises from the wall; ε the angle of the battered back of the wall with a vertical; φ the angle of friction or natural slope of the earth; φ' the angle of friction between the wall and the earth or—what Trautwine terms—the wall friction. H' is a fictitious length; θ an angle; both introduced only to simplify the formulas.

In most applications these expressions are modified by special features of each case. In what follows, the wall will be assumed vertical, the surface of the earth horizontal and not surcharged. Hence

$$\varepsilon = 0,\ \omega = 0,\ \rho = 0,\ H' = 0,\ \sin^2\theta = \frac{\sin\varphi\sin(\varphi + \varphi')}{\cos\varphi'}$$

or

$$tg^2\theta = tg\,\varphi\, tg(\varphi + \varphi')$$

and

$$P = \tfrac{1}{2}\gamma H^2 \frac{\cos\varphi}{\cos(\varphi + \varphi')} tg^2\left(45^\circ \mp \frac{\theta}{2}\right) =$$

$$\tfrac{1}{2}\gamma H^2 \frac{\cos\varphi'}{\cos^2(\varphi + \varphi')}(1 \mp \sin\theta)^2 \quad (2)$$

For our present purpose we can, however, not content ourselves with these formulas, but must take a more general view of what may actually occur. Considering the earth wedge, it may slide up or down the sliding plane and

up or down along the wall, at least relatively. The frictions along the sliding plane and along the back of the wall can act either way, and thus four different classes of cases are possible. The active pressure of the earth will tend to make the wedge slide down along both sliding plane and back of wall; the passive pressure will keep it from sliding upwards along the same planes. The frictions act accordingly either both upwards or both downwards. But when they act different ways, the one upwards and the other one downwards, pressures which may be designated as active-passive or passive-active may occur. The two components into which the weight of the earth wedge is resolved have each one out of two different directions, and hence are different in all four cases.

Confining ourselves at present to a vertical wall with the earth levelled off horizontal and not surcharged, and considering an earth wedge the sliding surface of which, assumed approximately plane, forms an angle β with the horizontal plane, the pressure of the wedge will be:

$$P = \tfrac{1}{2}\gamma H^2 \frac{\cot\beta \sin(\beta - \varphi)}{\cos(\beta - \varphi - \varphi')} \qquad (3)$$

where φ and φ' can be both positive (active pressure), the one positive and the other negative, or both negative. The value of β, which makes the pressure maximum or minimum, is found by differentiation of (3). With, as above, $tg^2\,\theta$ for $tg\,\varphi\,tg\,(\varphi + \varphi')$ the equation

$$\frac{d\,P}{d\,\cot\beta} = 0$$

gives

$$\cot\beta = \frac{tg\,\theta\,tg\left(45° - \frac{\theta}{2}\right)}{tg\,\varphi} = \frac{\sin\theta}{1 + \sin\theta}\cot\varphi \qquad (4)$$

Inasmuch as

$$\frac{d^2 P}{d\cot\beta^2} = -\frac{2\cos\varphi'\sin(\varphi + \varphi')}{[\cot\beta\cos(\varphi + \varphi') + \sin(\varphi + \varphi')]^2} =$$

$$-\frac{2\cos\varphi'\sin^3\theta}{\sin^2(\varphi + \varphi')}$$

is negative or positive according as *sin* θ is positive or negative the value (4) of β will either correspond to a maximum or a minimum pressure P.

But θ being defined only by the square of its *sin* or *tg*, the question arises what sign it should be given. It may even be questioned whether the equation $tg^2\,\theta = tg\,\varphi \cdot tg\,(\varphi + \varphi')$ will always be possible, or in other words, whether $tg\,\varphi\ tg\,(\varphi + \varphi')$ may not be negative, and θ consequently an imaginary quantity. If there were no relation between φ and φ' this would certainly occur. But we know that the acting wall friction φ' must always be less than, or at the most equal to, φ; for if the friction between earth and masonry were greater than between the earth particles mutually, then a thin layer would stick to the wall and the sliding occur, not along the wall, but along this layer, where the angle of friction is φ. Hence, whether φ or φ', or none or both of them is negative, $tg\,\varphi\ tg\,(\varphi + \varphi')$ will always be positive. With reference to the sign of θ, it will by inspection of (4) be evident that it should be taken positive or negative according as φ is positive or negative, for *cot* β must be positive if an earth wedge is actually formed. Equation (4) will therefore correspond to a maximum pressure whenever the wedge tends to slide down the sliding plane, *i. e.*, when φ is positive as for the active earth pressure; but it will correspond to a minimum when the wedge tends to slide up the sliding plane, *i. e.*, when φ is negative as for the passive earth pressure.

Transforming (3) by means of (4), we find the expression (2) for the maximum or minimum pressure, or

$$P\,\frac{max}{min} = \tfrac{1}{2}\gamma H^2\,\frac{cos\ \varphi}{cos(\varphi+\varphi')}\,tg^2\left(45^\circ - \frac{\theta}{2}\right) =$$

$$\tfrac{1}{2}\gamma H^2\,\frac{cos\,\varphi'}{cos^2(\varphi+\varphi')}\,(1 - sin\,\theta)^2 \qquad (5)$$

Likewise will equations (1), taken with the upper signs, represent the general formulas for P *max.* and P *min.* when φ, φ' and θ are taken with their respective signs.

With a view of representing the results of this analysis in a more conspicuous manner the annexed diagram has

been constructed. For the four different cases the variation of the active, passive-active, active-passive and passive earth pressure with the angle β is shown by the respective curves. On lines drawn from the lower edge of the wall under a variable angle β with the horizon the corresponding values of P (3) and $P\,max.$ or $P\,min.$ (5) are set out as radii vectores, and thus the curves were plotted. Only values of β between 0 and 90° were considered and the curves are dotted where the formula makes P negative. As physical constants were taken:

$$\varphi = \pm 30°,\ \varphi' = \pm 25°, \text{ and } \tfrac{1}{2}\,\gamma\,H^2 = 1.$$

The following table supplements the diagram:

TABLE OF VALUES OF $P \div \frac{1}{2}\gamma H^2$.

I = active. II = active-passive. III = passive-active. IV = passive.

Angle β	I φ pos., φ' pos.	II φ pos., φ' neg.	III φ neg., φ' pos.	IV φ neg., φ' neg.
0°	$-\infty$	$-\infty$	$+\infty$	$+\infty$
10°	$-2{\cdot}743$	$-1{\cdot}947$	$+3{\cdot}774$	$+8{\cdot}625$
15° 43′ 18″				$+7{\cdot}70294$
20°	$-0{\cdot}582$	$-0{\cdot}494$	$+2{\cdot}322$	$+8{\cdot}133$
30°	0	0	$+1{\cdot}831$	$+17{\cdot}218$
35°				$\pm\infty$
40°	$+0{\cdot}214$	$+0{\cdot}253$	$+1{\cdot}584$	$-12{\cdot}858$
45°	$+0{\cdot}263$	$+0{\cdot}338$	$+1{\cdot}503$	$-5{\cdot}562$
50°	$+0{\cdot}288$	$+0{\cdot}406$	$+1{\cdot}441$	$-3{\cdot}192$
53° 0′ 4″	$+0{\cdot}293593$			
60°	$+0{\cdot}290$	$+0{\cdot}503$	$+1{\cdot}366$	$-1{\cdot}366$
64° 3′ 30″			$+1{\cdot}35760$	
70°	$+0{\cdot}242$	$+0{\cdot}553$	$+1{\cdot}385$	$-0{\cdot}625$
72° 42′ 8″		$+0{\cdot}55661$		
80°	$+0{\cdot}149$	$+0{\cdot}522$	$+1{\cdot}902$	$-0{\cdot}191$
85°			$\pm\infty$	
90°	0	0	0	0

It is self-evident that for φ positive can β never be $< \varphi$, and the diagram shows this plainly by the pressure being negative for such values of β. For φ negative, on the contrary, β can be both $> \varphi$ and $< \varphi$.

* * *

The general formulas arrived at in the preceding investigation will now be applied to the following special cases:

(1) A cylindrical, circular, vertical vessel, the radius of which is R, is filled with earth up to a certain height, H. The bottom is not connected to the cylindrical surface. The weight of earth, carried by this bottom, is required.

(2) The same cylindrical vessel is filled with earth to the same level. What force must be exerted from beneath on the bottom in order to push it, with the earth it carries, upwards through the cylinder?

(3) A similar cylinder of radius R has, in some way or another, been gotten down to a depth H into a body of earth, the upper surface of which is horizontal, but else unlimited downwards and to all sides. What steady pressure is necessary to push this cylinder further down?

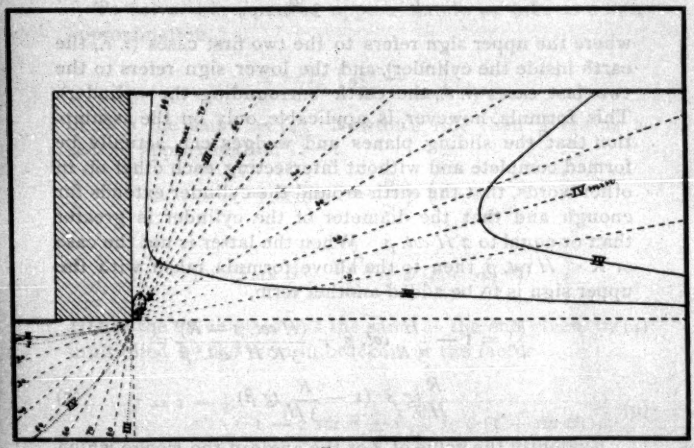


FIG. 1.

(4) The same cylinder reaches down to the same depth in the earth. What steady pull is necessary to pull it up?

The bearing of the latter two cases upon the question of pile-driving (or rather the load which can be supported by a pile) and pile-pulling lends a particular interest to them.

In all four cases if P_1 be the actual pressure per unit length on a plane element along a generatrix of the cylindrical surface and consequently $P_1 \sin \varphi'$ the frictional resistance; then the total friction on the cylindrical surface is $2\pi R . P_1 \sin \varphi'$. But the value of P_1 corresponding to

any given sliding plane is not the same as P of (3). For P is the pressure on a unit length of an infinitely long plane wall deduced from consideration of a prismatic wedge of earth; but P_1 must be the pressure of a wedge the two sides of which, instead of being parallel, are radial planes through the axis of the cylinder. Hence, P_1 to P as the ratio of the volumes of the two wedges.* Denoting by V_1 and V these volumes, the ratio is easily found to be

$$\frac{V_1}{V} = 1 \mp \frac{H}{3R} \cot. \beta \qquad (6)$$

where the upper sign refers to the two first cases (*i. e.*, the earth inside the cylinder), and the lower sign refers to the two last cases (*i. e.*, the earth surrounding the cylinder). This formula, however, is applicable only on the assumption that the sliding planes and wedges can actually be formed complete and without intersecting each other or, in other words, that the earth around the cylinder extends far enough and that the diameter of the cylinder is greater than or equal to $2\,H \cot. \beta$. When the latter is not the case or $R < H \cot. \beta$, then to the above formula taken with the upper sign is to be added another term,

$$\frac{V_1}{V} = 1 - \frac{H}{3R} \cot. \beta + \frac{(H \cot. \beta - R)^3}{3\,R\,H^2 \cot.^2 \beta} =$$

$$\frac{R}{H} tg\, \beta \left(1 - \frac{R}{3H} tg\, \beta\right) \qquad (7)$$

Evidently the value of β or the angle of the wedge which in each case makes P_1 a maximum or a minimum is different from the one given by (4). Differentiating the expression,

$$Q = \frac{\cot \beta . \sin (\beta - \varphi)}{\cos (\beta - \varphi - \varphi')} \left(1 \mp \frac{H}{3R} \cot. \beta\right)$$

and equating

$$\frac{d\,Q}{d.\ \cot.\ \beta} = o$$

* Rankine's or the rational theories would not agree with this proportioning. But considering what will actually happen, it seems admissible as a fair approximation.

we find

$$x = cot.\ \beta.\ cot.\ \theta.\ tg\ \varphi$$

as root of a somewhat complicated equation of the third degree, to wit:

$$x^3 - \tfrac{1}{2}\ cot.\ \theta\,(1 \pm \frac{3R}{H}\ tg\ \varphi - 3\ tg^2\ \theta)\ x^2 -$$

$$(1 \pm \frac{3R}{H}\ tg\ \varphi)\ x \pm \tfrac{1}{2}\ \frac{3R}{H}\ tg\ \varphi.\ cot\ \theta = o \qquad (8)$$

To solve this equation approximately we take as a first approximation

$$x = tg\left(45° - \frac{\theta}{2}\right)$$

or $cot\ \beta$ the same as (4). Newton's rule then gives as a second approximation

$$x = tg\left(45° - \frac{\theta}{2}\right)\left(1 - \frac{\frac{1}{2}}{1 - 2\ sin\ \theta \pm \frac{3R}{H}\ tg\ \varphi\ (1 + sin\ \theta)}\right)$$

Hence the value of $cot\ \beta$ is the same as the one given by (4) multiplied by the term in brackets or the factor

$$f = 1 - \tfrac{1}{2}.\ \frac{1}{1 - 2\ sin\ \theta \pm \frac{3R}{H}\ tg\ \varphi\ (1 + sin\ \theta)} \qquad (9)$$

Here the upper sign refers to the cases where the earth is inside the cylinder, the lower sign to where it is outside. When the earth is inside, and

$$R < f\,H\ \frac{sin\ \theta}{1 + sin\ \theta}\ cot\ \varphi$$

the values of β which make P_1 a maximum or minimum are found by substituting (7) for (6) in the expression for Q before differentiating. The equation by which

$$y = tg\ \beta$$

is determined will be of the second degree, to wit:

$$y^2 + 2\,tg\,\varphi.\,cot^2\,\theta.\,y - \left(tg^2\,\varphi.\,cot^2\,\theta + \frac{3}{R}\frac{H}{sin^2\,\theta}\frac{tg\,\varphi}{}\right) = o$$

whence

$$y = tg\,\beta = -\,tg\,\varphi\,cot^2\,\theta \pm \frac{1}{sin\,\theta}\sqrt{tg^2\,\varphi\,cot^2\,\theta + \frac{3}{R}\frac{H}{}tg\,\varphi} \tag{10}$$

which, according to our supposition, must be

$$< \frac{H}{R}$$

Comparing now equations (3), (6) and (7), we deduce the following formula for the total friction, F, on the cylindrical surface:

$$F = 2\,\pi\,R\,P_1\,sin\,\varphi' = \pi\,\gamma\,R\,H^2\,\frac{cot\,\beta.\,sin\,(\beta - \varphi)}{cos\,(\beta - \varphi - \varphi')}(1 \mp$$

$$\frac{H}{3\,R}\,cot\,\beta + A) \tag{11}$$

Here the upper sign refers to the case where the earth is inside the cylinder and the lower sign to where it is outside; and A is in the latter case always naught and in the first case

$$A = \begin{cases} \frac{(H\,cot\,\beta - R)^3}{3\,R\,H^2.\,cot^2\,\beta} & \text{for } R < H\,cot\,\beta \\ o & \text{for } R > H\,cot\,\beta \end{cases}$$

The maximum and minimum values of F will correspond to β determined by the equation

$$cot\,\beta = f.\,\frac{tg\,\theta.\,tg\left(45^\circ - \frac{\theta}{2}\right)}{tg\,\varphi} = f\,cot\,\varphi.\,\frac{sin\,\theta}{1 + sin\,\theta} \tag{12}$$

where f is defined by (9); or, when the earth is inside the cylinder and

$$R < H\,cot\,\beta$$

by the equation

$$cot\,\beta = \frac{tg\,\theta}{tg\,\varphi}\,\frac{sin\,\theta}{-\,cos\,\theta \pm \sqrt{1 + \frac{3}{R}\frac{H}{}tg^2\,\theta.\,cot\,\varphi}} \tag{13}$$

[*To be concluded.*]

INVESTIGATION OF A BITUMEN FROM PARK COUNTY, MONTANA.*

By Wm. C. Day and A. P. Bryant.

Although asphalt and allied materials are known to occur at many localities in the United States, comparatively little has been accomplished in the way of their analysis and investigation. Results thus far secured have been confined chiefly to a few sources favorably situated for transportation at low rates. The available supply of asphalt at present largely exceeds the demands. Since, however, the uses to which this material may be applied are increasing, and since, further, no one source yields a product suitable for all purposes we have thought it worth while to place on record the facts and figures secured in connection with a material from a new source in the West.

The substance under consideration was taken from the property of Mr. C. J. Lakin, of Miles City, Montana.

The sample consisted of about one liter of a brownish-black material, liquid enough to flow very slowly at ordinary temperatures, and possessed of an unpleasant and quite pronounced odor.

ANALYSIS.

Determination of Water.

0·4647 grams of bitumen gave 0·0314 grams of water absorbed in a chloride of calcium tube after two hours heating in a U tube immersed in boiling water; a current of dry air was passed through the tube during this time.

Percentage of water found, 6·76.

There was no evidence whatever of any change in the material other than the loss of water.

Determinations of Carbon and Hydrogen.

No. 1.—0·6462 grams of substance gave 1·8672 grams of carbon dioxide and ·5365 grams of water.

* Read at the stated meeting of the Chemical Section, held June 19, 1894.

No. 2.—0·4097 grams of substance gave 1·2144 grams of carbon dioxide and ·3449 grams of water.

Carbon found, No. 1, 78·80, No. 2, 80·81.

Hydrogen found, No. 1, 9·22, No. 2, 9·35.

Determination of Mineral Matter.

No. 1.—0·8426 grams of substance gave on combustion 0·0058 grams of residue.

No. 2.—0·3324 grams of substance gave on combustion 0·0023 grams of residue.

Percentage of ash, No. 1, 0·69 per cent.

Percentage of ash, No. 2, 0·69 per cent.

Determination of Sulphur.

0·7144 grams of substance gave (using Liebig's method) 0·1471 grams of barium sulphate.

Percentage of sulphur found, 2·83.

A determination of nitrogen gave only a trace.

The following analysis of commercial interest was also made:

MATERIAL SOLUBLE IN CARBON DISULPHIDE.

5·5300 grams of dry substance gave 5·2540 grams of material (bitumen) soluble in carbon disulphide.

Percentage of bitumen found, 95·00.

The weight of the material insoluble in carbon bisulphide was 0·2760.

Percentage of foreign organic matter, 4·99.

The material soluble in carbon disulphide was treated with gasoline, and the percentage of matter soluble in gasoline (petrolene) was thus determined.

5·5300 grams of the original substance gave 4·4240 grams of material soluble in gasoline.

Percentage of petrolene found, 80·00.

The foreign organic matter found consists largely of fragments of birds' feathers, leaves and insects, which had probably accidentally been caught and submerged in the pitch.

The following distillation experiments were made:

Seventy-four grams of the substance were introduced into a distilling flask by aid of a filter pump; the viscosity

of the material was such that it took several hours to transfer about 100 cubic centimeters to the flask.

A Bunsen flame was applied directly to the flask; the material frothed considerably, giving a gas which was collected and measured. The gas given off at this stage amounted to 2,250 cubic centimeters. When a thermometer placed with the bulb in the vapor (*i. e.*, a little below the side tube of the distilling flask) showed 98° C. the frothing ceased and a liquid distilled over between 98° and 110°; the weight of this fraction was 6·75 grams. The second fraction was taken between the limits 110° and 170°, its weight was 2·3 grams; the third fraction was taken between 170° and 225°; its weight was 8·75 grams; the last fraction was from 225° to the limit of the thermometer; it weighed 22·5 grams. The last fraction was accompanied by the more rapid evolution of gas which had decreased at 98°. Between 98° and 225°, 1,000 cubic centimeters of gas were produced.

The amount of gas evolved at this final stage was 2,500 cubic centimeters, thus making in all 5,750 cubic centimeters of what, on burning, proved to be a good illuminating gas.

A number of tests for aromatic hydrocarbons and derivatives yielded negative results.

The following summary of the analytical results obtained shows how the material in question compares in chemical constitution with Trinidad asphalt, which has heretofore supplied a large percentage of the demand in the United States:

	*Trinidad.**	*Park Co., Montana.*
Water,	—	6·76
Carbon,	85·89	79·81
Hydrogen,	11·06	9·29
Oxygen,	·56	·62†
Nitrogen,	—	trace.
Sulphur,	2·49	2·83
Ash,	—	0·69
	100·00	100·00

* Analyst, Bowen.
† By difference.

These figures are only approximately comparable, since those for the Trinidad material are calculated on the pure

and dry asphalt, exclusive of earthy and foreign organic matter.

A comparative investigation of gilsonites and asphalts from a number of new sources in the United States is now being carried out by the authors, and the present paper may be regarded as preliminary to a more comprehensive one, which, it is hoped, may be presented in the fall.

SWARTHMORE COLLEGE,

Swarthmore, Pa., June 19, 1894.

ANTHRACITE COAL NEAR PERKIOMEN CREEK.*

BY OSCAR C. S. CARTER,

Prof. Geology and Mineralogy, Central High School, Philadelphia.

A vein of coal twenty-six inches thick has been discovered on the Shirley farm at Arcola Station, on the Perkiomen Railroad, about twenty-five miles from Philadelphia. The vein is located near where the Skippack Creek empties into the Perkiomen Creek. An expert miner has been working on the vein for the past three weeks, and pronounces the coal of fine quality. A company is being formed for the purpose of working the coal. There are a number of smaller veins in the immediate vicinity, and it is thought that coal can be mined in large quantities on this and the adjoining farms. Several mining experts from Pottsville were at Arcola and examined the outcroppings of coal, and pronounced the indications the very best, and before leaving made a liberal offer for the farm. Work has been temporarily suspended on account of the water flowing in from the creek.

The above notes of January 6, 1894, are from local newspapers. A visit to the locality showed me that the coal seam is found at the base of a high hill, which slopes steeply to the Skippack Creek, near where it empties into

* Read at the stated meeting of the Chemical Section, held June 19, 1894.

the Perkiomen. The rock in the vicinity is red sandstone of triassic age, and numerous exposures along the Skippack show that it dips gently at angles of from 12° to 15°. The sandstone is not a conglomerate, but is similar to that seen along the Schuylkill from Norristown to Phœnixville. At the base of the hill, on a level with the creek, is found a bed of hard, black carbonaceous slates. These are conformable with the sandstone, but the line of contact is sharp. These slates contain iron pyrites, and many pieces show a play of colors like iridescent coal. The sandstone resting on the slates is over 100 feet in thickness. The coal is found in the slate, about four feet from the top of the slate bed. The coal seam is said to be twenty-six inches thick at the widest part, but gradually thins out until it becomes an inch thick. The hole was partially filled with ice at that time, so that the true thickness could not be determined. Coal outcrops along the banks of the stream near the water-line; about one ton had been taken out. Two men were at work running a tunnel through the hill and supporting it with heavy timbers. One of the old residents of the township informed me that it was known many years ago that there was coal in the hill, and that fifty years ago Mr. Peters, who then owned the farm, ran a shaft through the hill for a distance of 100 feet; it was kept on an incline so as to drain off the water. In the middle of this passage-way they sank a shaft ten feet deep. The shaft unfortunately was in the sandstone and did not reach the slate, which holds the coal. This old shaft is now filled up. An examination of the slate and coal thrown out failed to show any fossils, but Mr. Shirley informed me that he had found one which resembled a poplar leaf. Several specimens of coal were secured for analysis. It is a hard, compact and lustrous anthracite. On analysis I found:

Volatile and combustible matter,	6 50
Fixed carbon,	62·84
Ash,	30·6

This sample contained some slate, which accounts for the high percentage of ash. I made an analysis of another specimen much purer, which showed it to be a good coal:

Water,	·95
Volatile and combustible matter,	5·83
Fixed carbon,	83·8
Ash,	9·50
	100·08

A furnace assay showed that one gram of coal reduced 31·78 grams of lead from litharge, thus showing from the usual calculation that its value in units of heat is 7,552.

The following table is given for comparison:

	Heat Units.
Peat	= 3,000
Wood	= 4,000
Lignite	= 5,000
Carbon	= 8,080
Hydrogen	= 34,462

On the country road between Eagleville and Arcola was noticed a red-and-white sandstone, containing irregular black patches of organic matter. On splitting the rock, layer after layer of this black carbonaceous matter was seen. The sandstone was white where in contact with, or near to, the organic matter, but was red some distance off. The red coloring matter of the sandstone is due to red hematite. This is a fine example of organic matter, acting as a reducing agent and reducing the ferric oxide (hematite), which is insoluble in water to ferrous oxide, which is soluble in water containing carbonic acid gas. Water filtering through the bed planes had dissolved the ferrous oxide and thus leached out the red coloring matter of the sandstone, leaving it white.

Precisely the same kind of rock as the above was noticed in the new red sandstone belt in a quarry near Three Tuns, about three miles from Ambler.

The triassic coals are exceedingly interesting from a geological standpoint, because they occur in more recent formations than coals of the carboniferous period and are thus of a later age. There are other instances of the occurrence of coal in Montgomery County. In the new red sandstone at Norristown, on Elm Street near the Stony Creek Railroad, a seam of coal an inch in thickness was found. It only extended for a few feet and was not very

wide. It was found about twelve feet below the surface, while grading the street. I also found the striated stem of a fossil plant in the sandstone.

[See "History of Montgomery County," p. 17.]

This coal was of a deep black color, pitchy in appearance, very brittle and broke with a conchoidal fracture.

At Gwynedd, Montgomery County, in the new red, is found a bed of carbonaceous shale, colored black by traces of coaly matter which it contains. In Lower Providence Township, Montgomery County, about one-half mile west of the Trooper was found a seam of coal three inches thick. It was used by the village blacksmith. During the summer of 1883, men working upon the new tunnel at Phœnixville discovered a two-inch seam of coal in the sandstone. It may be that a patient examination of these so-called triassic slates, which underlie the sandstone in Montgomery County, will disclose beds of workable coal in more than one locality. No systematic search has ever been made for coal and very few deep artesian borings have been made in the new red in Montgomery County. In drilling the deep artesian well at Lansdale, a bed of black carbonaceous slates was passed through, and under these slates was found a bed of coal. Dr. A. D. Markley, of Hatboro, informs me that a thick bed of coal was passed through in drilling an artesian well at North Wales; it was found at a depth of 150 feet. These same triassic rocks have yielded large quantities of good coal in Virginia and North Carolina. In the earliest days of coal mining, more coal was taken from the red sandstone rocks of the Richmond basin than was mined in Pennsylvania. In 1822, about 48,000 tons were produced, which was twelve times the amount shipped by Pennsylvania. (See "Mineral Resources," 1886.) In 1833, about 142,587 tons of triassic coal were mined in Virginia, or about one-third the amount of anthracite produced in Pennsylvania. In 1887 but one mine was worked, and it produced 30,000 tons. During this year several new companies were organized to mine coal in this field. The triassic field in Virginia has an area of 180 square miles; about two square miles of territory have been

worked over. These coal beds occur in an immense sandstone trough which rests on a granite floor; the coals are mainly bituminous, although a natural coke is mined. This coke was formed by an intrusion of trap. An average analysis of Richmond coal gives:

Water	1·34
Volatile matter	32·45
Fixed carbon	57·05
Sulphur	1·98
Ash	7·18

In North Carolina, triassic coals are mined near the Deep and Dan Rivers. In the Dan River field, two coal beds have been found; one bed of soft coal has a thickness of five feet; the other, of harder coal, has a thickness of three feet. On the opposite side of the valley, a bed of soft coal, free from slate and nine feet in thickness, has been found; some good anthracite has also been found. Mr. Robson, who has been exploring the district, says: the Dan River coal deposits may be taken as available for fuel supplies for a distance of fifty miles; the width of the basin is three and one-half miles. He has driven 800 feet of adits, in length from thirty down to twenty feet, and ascertained the existence of persistent seams of coal over five feet in thickness. These coals are high in sulphur. The coal of the Deep River is also high in sulphur, averaging about three per cent.; it occurs in dark, carbonaceous slates and shales, and has been found for a distance of thirty miles along the outcrop. During the late war, about 50,000 tons were taken out to supply the blockade runners at Wilmington and also to supply the arsenals. The following is an average analysis:

Moisture	1·79
Volatile and combustible matter	29·56
Fixed carbon	58·30
Ash	7·46
Sulphur	2·89
	100·00

JOHN HOWARD GIBSON.

John Howard Gibson, whose untimely death cut short what promised to be a career of exceptional usefulness, was born March 13, 1857, and died April 6, 1894, having just completed his thirty-sixth year. Mr. Gibson was the son of Henry Clay Gibson, one of Philadelphia's most prominent citizens and well known as a liberal patron of the fine arts, and his wife, Mary Klett.

He was graduated from the University of Pennsylvania in the class of 1877. His connection with the Franklin Institute began in 1878, when he was elected to membership. He manifested from the beginning of this connection a warm interest in its affairs and remained to the end of his life one of its most active members and officers. He was especially interested in the growth of its library and served most acceptably for a number of years on the Committee on Library.

He was elected a member of the Board of Managers in the year 1893, and at once made his influence felt in that body by his activity in promoting every movement looking to the advancement of the interests of the institution. His conspicuous advocacy in the Board of measures having for their object to secure for the Institute a new building, awakened a renewed interest in the subject among his colleagues, and whether this important object shall be realized sooner or later, the Institute owes a debt of gratitude to its deceased officer for his unflagging zeal in endeavoring to bring it about.

His personal relations with his colleagues of the Board and fellow-members were characterized by uniform courtesy and amiability.

The manner of his untimely taking off was peculiarly sad. His children, to whom he was devotedly attached, were afflicted with a contagious malady, which, in his solicitous attendance upon them, he contracted, and which, within a few hours, terminated his life. Thus, all too early was

closed a life which, had it been spared, would have been devoted to noble and unselfish objects; and the Franklin Institute, in whose work he took special pride, and in whose future he had unbounded faith, may well regret the loss of a friend so devoted to its interests, and so willing to give freely of his time and energy and means to serve it.

Mr. Gibson married Susan Worrall, daughter of Frederick Sickel Pepper, of Philadelphia, by whom he had three children. His widow and children survive him.

{ F. Lynwood Garrison.
{ William H. Wahl,

Philadelphia, June 8, 1894.

Accepted at the stated meeting of the Board of Managers June 27, 1894, and ordered to be referred to the Committee on Publications and reported to the Institute.

H. L. Heyl, *Actuary.*

BOOK NOTICES.

The Mineral Industry, its statistics, technology and trade, from the earliest times to the close of 1893. New York: Scientific Publishing Company, 1894. 4to. Pp. 894. Price, $5.

The second volume of *The Mineral Industry*, edited by Mr. Rothwell, with the assistance of a number of collaborators, is a comprehensive review, technical and commercial, of the mining and metallurgical industries of the world. Each branch of the subject has been confided to an expert thoroughly familiar with the subject, and the result is the production of a volume which gives in concise encyclopædic form the latest and most approved methods in use for producing, selecting and refining the useful minerals and metals, and the amounts and values of each produced and consumed in all parts of the world. The work is remarkably comprehensive, and many of the special articles are extremely valuable contributions to the history of the art to which they relate.

The work is beyond comparison in thoroughness with anything of the kind produced elsewhere, and its value to the engineer, the metallurgist, the man of business and the statistician, cannot be over-estimated. Its compilation represents an enormous amount of work, demanding the highest order of special skill and knowledge, and its successful completion reflects the highest credit upon its accomplished editor. W.

The Metallurgy of Lead and the Desilverization of Base Bullion. By H. O. Hoffman, E.M., Ph.D. Second Edition. The Scientific Publishing Co., New York, 1894.

No branch of metallurgy, except the manufacture of pig iron and steel, has made more rapid progress in the United States than the smelting of argentiferous lead. A new treatise on this subject has been a desideratum for many years. Professor Hoffman has now supplied this want and presented us with a book which is thoroughly modern, and which must be regarded as one of the most valuable recent contributions to the literature of metallurgy. It is admirably planned and well written. After some introductory chapters on the history of the metal, and its occurrence and distribution in nature, the author gives an account of the manner in which ores are bought and received by the smelting works, including the methods of sampling and assaying. The main part of the book is devoted to the discussion of the metallurgical treatment of the ores, and this is followed by descriptions of the various processes of desilverizing the base bullion.

Considerable space is allotted to theoretical discussions, and, wherever possible, the chemical reactions are explained. The descriptions of metallurgical operations and appliances are very accurate and complete, special prominence being given in this respect to modern American practice.

The value of the book is greatly enhanced by numerous illustrations, which are mostly drawn to scale.

The rapid technical methods of analysis, of which accurate and detailed directions are given, will doubtless prove very acceptable to a large class of readers.

H. F. K.

Hendricks' Architects' and Builders' Guide and Contractors' Directory of America. Fourth Edition. New York: S. E. Hendricks & Co. 1894. 4to. 800 pp. Price, $5.

The scope of this useful reference book will appear from the following explanatory statement quoted from the publishers' prospectus: "This complete dictionary of all the constructive industries of the United States contains over 175,000 names, addresses and business classifications, comprising builders and contractors of material and construction in the building and kindred industries; with full lists of the manufacturers of, and dealers in, everything employed in the manufacture of material and apparatus used in those industries, from the raw material to the manufactured article, and from the producer to the consumer." The contents embrace also an extensive list of American architects, including those of Canada, Cuba and Mexico.

As will be perceived from the foregoing, the work is designed to be a professional and business directory, covering every branch of the arts and industries connected with building construction. The classification adopted is elaborate but very convenient. Thus, in the index of contents will be found every variety of brick, each classified under its special heading; and the same elaboration has been applied apparently to the other trades, such as engineers' supplies, boiler makers, heaters, heating specialties, plumbers'

supplies and specialties, slate, cements, building stone, roofing tiles, pumps, sheet metal goods, fire-proof building materials, etc.

So far as we are competent to judge of the merits of a work of its class, the directory is unusually comprehensive, and admirably classified for reference, and we have no reason to question that it is as accurate as, in the nature of things, a work of the kind can be made. It should prove an extremely handy reference book for all having to do with building construction. W.

Wilson's Cyclopædic Photography: a complete hand-book of the terms, processes, formulæ and appliances available in photography, arranged in cyclopædic form for ready reference. By Edward L. Wilson, Ph.D. New York: Published by Edward L. Wilson, No. 853 Broadway. 1894. Large 8vo. 522 pp. Price, $4.

The author's long experience as a photographer and photographic journalist and author, qualifies him perhaps better than any other expert to undertake the preparation of a work of the character of this one. So far as a general knowledge of the subject enables us to judge of the merits of the work, it is comprehensive, concise and accurate, and it should prove specially useful to the class for whose benefit it has been prepared. The arrangement is alphabetical by subjects, the catch-word or words are distinctly displayed in black body-letter, and the type is large and clearly printed. The numerous illustrations, many of which have been prepared especially for the work, add to its value. W.

The Transition Curve by Offsets and by Deflection Angles. By C. L. Crandall, C.E., Associate Professor of Civil Engineering, Cornell University. New York: John Wiley & Sons. 1893. Price, $1.50.

The author believes that in this little book are developed for the first time accurate methods for applying the true transition curve, or that curve in which the curvature increases directly with the distance, to curves of large total deflection and to both the deflection and the offset methods.

The book is intended primarily for use by students of civil engineering in colleges, but it is believed that the complete set of tables given will render the methods here explained at least as rapid and convenient in actual use in the field as are the more restricted or the merely approximate methods now in use. T.

Surveying and Surveying Instruments. By G. A. T. Middleton, Associate of the Royal Institute of British Architects. New York: Macmillan & Co. 1894. Price, $1.25.

This work is a reprint of a series of articles which have appeared in the *Building News*. It is strictly elementary, and proposes simply to describe concisely the operations and instruments used in land surveying. It is, of course, based upon English methods, and it is therefore not strange that the theodolite comes in for description and illustration. The work is pretty freely illustrated by photo-engravings, which rather lack in clearness and in firmness of lines. T.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR JUNE, 1894.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 30, 1894.

GENERAL REVIEW.

The average temperature for June was 69°.6, which is about 0°.6 above the normal. The first half of the month was cooler than usual, and the last half warmer. The total excess of temperature during the month amounted to about 33°.

The warmest days occurred on the 22d, 23d and 24th, and unusually high temperatures were recorded.

The lowest temperatures were recorded on the 6th, 7th and 8th, on which dates a few stations reported frosts, but they were not damaging.

Owing to the wet and cold, crops made slow progress until the latter half of the month, when favorable conditions prevailed.

From January 1, 1894, to June 30, 1894, the excess in temperature at Philadelphia was 412°; at Erie, 491°, and at Pittsburgh, 316°.

For the same period the excess in precipitation at Philadelphia was 1.50; while at Erie the deficiency was 3.10, and at Pittsburgh, 4.44.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
June, 1888, ...	68°.6	3.04
1889, ...	66°.5	5.43
1890, ...	70°.3	3.42
1891, ...	68°.7	4.50
1892, ...	71°.7	5.64
1893, ...	69°.6	3.12
1894, ...	69°.6	2.57

The means of the daily maximum and minimum temperatures, 81°.5 and 57°.7, respectively, give a monthly mean of 69°.6, which is the same as the corresponding month of 1893.

The average daily range was 23°.8.

Highest monthly mean, 73°.8 at Swarthmore.

Lowest monthly mean, 64°.4 at Kane.

Highest temperature recorded during the month, 102° on the 24th at Hamburg.

Lowest temperature, 30° on the 7th at Dyberry.

Greatest local monthly range, 64° at Saegerstown.

Least local monthly range, 47° at Cassandria.

Greatest daily range, 50° at Lock Haven.

PRECIPITATION.

The average precipitation for the State, for the month, 2.57 inches, is a deficiency of 1.38. While rains were frequent, they were light, and, owing to the saturated condition of the ground from the rains in May, were sufficient for agricultural purposes.

The largest monthly totals were Phœnixville, 5.31; State College, 4.60; Seisholtzville, 4.32; Westtown, 4.08; Hollidaysburg, 3.87; Forks of Neshaminy, 3.83.

The least were Pittsburg, 0.61; Reading, 0.91; Davis Island Dam, 0.96; South Eaton, 1.09; Doylestown, 1.35; Beaver Dam, 1.38.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 10; clear days, 13; fair days, 12; cloudy days, 5.

BAROMETER.

The mean pressure for the month, 30.00, is about .03 above the normal. At the United States Weather Bureau Stations, the highest observed was 30.32 at Harrisburg on the 14th, and the lowest 29.58 at Erie on the 2d.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Hollidaysburg, 13th, 16th, 17th, 18th, 22d, 23d, 24th, 27th; Quakertown, 4th, 12th, 16th, 24th, 26th, 30th; Cassandria, 4th, 12th, 16th, 17th, 18th, 22d, 23d, 24th, 25th, 27th; Johnstown, 4th, 12th, 16th, 17th, 22d, 23d, 24th, 25th, 26th, 27th; Emporium, 3d, 12th, 16th, 17th, 18th, 23d, 25th, 27th; Mauch Chunk, 19th, 23d, 24th; State College, 2d, 12th, 18th, 19th, 25th; West Chester, 4th, 13th, 24th, 30th; Coatesville, 4th, 5th, 7th, 24th, 26th; Kennett Square, 4th, 13th, 24th; Phœnixville, 24th; Westtown, 4th, 12th, 24th, 30th; Grampian, 12th, 16th; Lock Haven, 1st, 4th, 7th, 12th, 16th, 17th, 18th, 23d, 24th, 25th, 27th; Bloomsburg, 13th, 18th, 19th, 24th; Carlisle, 4th, 7th, 12th, 18th, 19th, 23d, 25th, 26th; Harrisburg, 4th, 7th, 12th, 13th, 16th, 18th, 23d, 26th; Uniontown, 4th, 12th, 16th, 17th, 22d, 24th, 25th, 26th, 27th, 30th; Huntingdon, 12th, 16th, 17th, 18th, 19th, 23d, 25th;

Lebanon, 4th, 7th, 12th, 16th, 18th, 19th, 26th; Coopersburg, 12th, 16th, 17th, 19th, 23d, 24th, 26th, 30th; Kane, 3d, 7th, 12th, 18th, 25th; Smethport, 12th, 17th, 23d, 24th, 25th, 27th; Easton, 4th, 12th, 13th, 16th, 17th, 18th, 19th, 24th, 26th, 27th, 30th; Logania, 16th; *Philadelphia* [Weather Bureau], 4th, 5th, 13th, 24th, 26th, 30th; [Centennial Avenue], 4th, 13th, 19th, 24th, 26th, 30th; [Locust Street], 4th, 13th, 24th, 26th, 30th; Blooming Grove, 1st, 4th, 12th, 16th, 17th, 18th, 19th, 20th, 24th, 29th; Shingle House, 3d, 12th, 17th, 23d, 24th, 25th, 26th; Somerset, 6th, 7th, 16th, 24th, 26th; Wellsboro, 3d, 12th, 18th, 25th; Lewisburg, 23d, 24th, 25th; Dyberry, 4th, 12th, 18th, 19th, 20th, 24th, 26th, 27th, 30th; Honesdale, 12th, 18th, 23d, 27th, 29th; South Eaton, 2d, 3d, 4th, 12th, 18th, 24th, 25th.

Frost.—Pittsburgh, 7th, 8th; Saegerstown, 5th; Uniontown, 7th; Selins Grove, 2d, 3d; Somerset, 6th, 7th; Dyberry, 5th, 7th, 8th; Honesdale, 7th, 8th; Hamlinton, 7th, 8th.

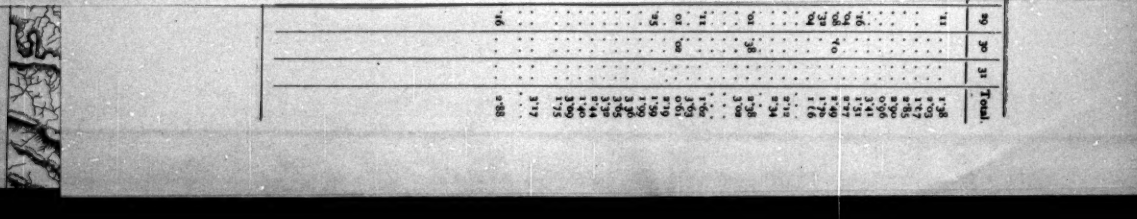
Hail.—Hollidaysburg, 17th, 18th, 22d, 23d; Emporium, 12th; State College, 18th; Kennett Square, 14th; Phœnixville, 4th; Saegerstown, 24th; Kane, 12th; Smethport, 16th; *Philadelphia* [Centennial Avenue], 30th; Blooming Grove, 16th; Shingle House, 3d; Somerset, 16th; Wellsboro, 12th; Dyberry, 30th; York, 4th, 12th.

Solar Halo.—Philadelphia [Weather Bureau], 19th; [Centennial Avenue], 12th, 15th, 19th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for June, 1894.

County	Station	Elevation above Sea Level (feet).	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers
Allegheny,	Pittsburgh,	820	72·0	95	23	42	7	83·1	60·0	23·1	34	0·61	. . .	. . .	11	14	15	1	NW	O. D. Stewart, W. B
Berks,	Hamburg,	380	71·2	102	24	44	7, 8	84·2	58·3	25·9	36	1·40	. . .	. . .	10	3	24	3	W	William Shipe.
Berks,	Reading,[1]	280	70·8	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0·91	. . .	. . .	11	. . .	. . .	. . .	. . .	Franklin Yager.
Blair,	Altoona,	1,181	73·0	95	24	47	8	83·4	62·6	20·8	26	2·66	. . .	. . .	12	. . .	. . .	. . .	. . .	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	68·9	97	22	37	7	85·4	52·3	33·1	48	3 87	. . .	. . .	12	13	14	3	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	66·9	90	22, 24	37	8	76·8	57·0	19·8	31	1·64	. . .	. . .	13	9	14	7	SW	G. W. T. Warburton
Bucks,	Forts of Neshaminy[1] (29 days),	394	72·1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3.83	. . .	. . .	14	14	12	3	W	J. C. Hilsman.
Bucks,	Quakertown,	536	69·1	96	23	39	8	82·8	56·4	25·4	34	3·22	. . .	. . .	12	6	23	1	SW	J. L. Hancock.
Cambria,	Cassandria,	2,100	70·8	90	22, 24	43	5	77·5	64·2	13·3	26	1·67	. . .	. . .	10	11	14	5	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	70·0	98	23	42	7, 8	83·8	56·3	27·5	40	2·12	. . .	. . .	16	7	16	7	SW	E. C. Lorents.
Cameron,	Emporium,	1,050	67·4	91	22, 24	39	7	80·2	54·6	25·6	38	3·06	. . .	. . .	11	8	20	2	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	69·6	97	23	38	7	83·2	56·1	27·1	44	2·87	. . .	. . .	11	16	9	5	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	68 3	92	23	41	2	79·1	57·5	21·6	35	4·60	. . .	. . .	16	7	13	10	W	Prof. Wm. Frear.
Chester,	West Chester,	455	71·0	95	24	44	7	80·7	61·4	19·3	28	3·74	. . .	. . .	11	19	5	6	S	J. C. Green, D.D.S.
Chester,	Coatesville,	380	70·6	98	24	42	8	82·5	58·6	23·9	34	2·29	. . .	. . .	8	18	11	1	S	W. T. Gordon.
Chester	Kennett Square,	475	70·6	95	23	41	1	83·0	58·2	24·8	38	2·45	. . .	. . .	10	19	9	2	SW	B. P. Kirk.
Chester,	Phœnixville,	190	71·4	97	23	44	7, 8	81·7	61·0	20·7	33	5·31	. . .	. . .	11	13	6	11	NW	Knowles Croskey.
Chester,	Westtown (27 days),	350	69·7	93	24	41	6	80·0	52·4	20·6	29	4·08	. . .	. . .	8	10	7	10	W	John D. Carter.
Clearfield,	Grampian,	1,450	69·0	94	22	42	6, 7, 8	80·5	57·5	23·0	32	2·17	. . .	. . .	8	7	19	4	NW	Nathan Moore.
Clinton,	Lock Haven,	560	70·8	101	23	40	1, 8	87·1	54·6	32·5	50	3·52	. . .	. . .	11	15	4	11	W	Prof. J. A. Robb.
Columbia,	Bloomsburg—‡ State Normal School,	500	69·1	94	24	43	8	80·4	57·8	22·6	33	2·25	. . .	. . .	10	18	3	9	W	Prof. J. G. Cope.
Crawford,	Meadville— Divinity Hall,	1,200	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prf. J. H. Montgomery.
Crawford,	Saegerstown,	1,100	65·7	95	23	32	7	81·3	50·1	31·2	46	1·59	. . .	. . .	9	14	12	4	NW	J. G. Apple.
Cumberland,	Carlisle, (29 days),	480	71·4	100	24	42	8	84·2	58·6	25·6	37	2·05	. . .	. . .	8	16	7	6	S	J. E. Pague.
Cumberland,	Carlisle— Dickinson College,	480	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	H. E. Smith.
Dauphin,	Harrisburg,	361	71·0	95	23	47	8	81·0	61·0	20·0	28	3·25	. . .	. . .	12	. . .	. . .	. . .	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	190	73·8	98	23, 24	47	7, 8	84·0	63·7	20·3	30	2·93	. . .	. . .	8	6	20	4	. . .	Prof. S. J. Cunningham
Erie,	Edinboro,[2]	1,400	68·0	91	24	35	6	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	W	C. F. Sweet.
Erie,	Erie,	681	68·0	92	24	40	6, 8	76·0	60·0	16·0	34	2·88	. . .	. . .	12	12	10	8	SW	P. Wood, W. B.
Fayette,	Unlontown, (26 days),	1,000	72·0	93	24	38	7	84·6	59·4	25·2	36	1·40	. . .	. . .	. . .	15	9	2	SW	Wm. Hunt.
Franklin,	Chambersburg,	618	70·4	96	24	43	7	83·0	57·8	25·2	39	3·17	. . .	. . .	8	13	8	9	W	J. C. Boggs.
Fulton,	McConnellsburg,	875	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	T. F. Sloan
Huntingdon,	Huntingdon— The Normal College,	650	68·8	98	24	38	2, 8	84·1	53·4	30·7	44	3·56	. . .	. . .	14	24	4	2	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. S. C. Schmucker.
Juniata,	Kilmer,[2]	475	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3·65	. . .	. . .	. . .	. . .	. . .	. . .	. . .	R. J. Mickey.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	70·2	96	23	42	7	82·4	58·0	24·4	33	2·54	. . .	. . .	9	15	15	. . .	W	W. E. Bushong.
Lawrence,	New Castle,	932	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Wm. T. Buts.
Lebanon,	Lebanon,	458	69 9	97	23	38	8	82·2	57·7	24·5	33	1·91	. . .	. . .	12	14	11	5	SW	G. W. Hayes, C.E.
Lehigh,	Coopersburg,	520	69·9	92	23	44	7, 8	79·2	60·5	18·7	29	2·58	. . .	. . .	15	14	11	5	SW	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	66·0	94	23	36	7	79·2	52·8	26·3	42	2·87	. . .	. . .	10	7	11	8	N	J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	70·4	97	23	37	7	85·1	55·6	29·5	49	1·78	. . .	. . .	7	24	3	3	W	A. W. Betterly.
McKean,	Kane,	2,000	64·4	90	24	35	7	76·1	52·7	23·4	45	2·34	. . .	. . .	12	16	10	4	SE	C. H. Kemp.
McKean,	Smethport,	1,500	64·8	91	22, 23	35	2	78·2	51·4	26·8	41	3·65	. . .	. . .	10	17	10	3	SW	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	67·8	94	23	33	7	81·4	54·2	27·2	44	1·78	. . .	. . .	7	26	. .	4	S	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	72·2	98	23, 24	45	8	83·3	61·0	22·3	32	1·74	. . .	. . .	10	18	9	3	W	Charles Moore, D.D.S
Montgomery,	Skippack,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	B. W. Dambly.
Northampton,	Easton— Lafayette College,	325	70·8	94	23	42	8	82·4	59·2	23·2	32	2·54	. . .	. . .	9	17	8	5	. . .	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	72·2	101	23	42	7	86·3	58·2	28·1	40	2·78	. . .	. . .	13	16	6	8	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	73·0	97	24	48	6	82·3	63·3	19·0	30	1·63	. . .	. . .	9	13	12	5	SW	L. M. Dey, W. B
Philadelphia,	1529 Centennial Avenue,	120	73·0	99	24	47	8	83·5	62·6	20·9	32	2·56	. . .	. . .	7	13	12	5	SW	John Comly.
Philadelphia,	3911 Locust Street,	100	72·9	99	23	47	7	83·4	62·4	21·0	29	2·74	. . .	. . .	8	10	6	8	SW	R. L. Paddock.
Pike,	Bloomling Grove,[2]	. . .	67·7	98	30	45	6	. . .	. . .	. . .	. . .	3·51	. . .	. . .	11	1	23	6	S	John Grathwohl.
Potter,	Shingle House,	1,475	64·6	93	24	35	6, 7	78·1	51·1	27·0	40	3·36	. . .	. . .	14	11	14	5	W	C. D. Voorhees, M.D
Schuylkill,	Girardville,	1,000	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	E. C. Wagner.
Snyder,	Selins Grove,	455	70·5	97	30	40	3	88·9	52·1	36·8	45	2·40	. . .	. . .	11	21	. .	9	SW	J. M. Boyer,
Somerset,	Somerset,	2,250	70·4	94	23	42	7	80·2	60·6	19·6	31	3·32	. . .	. . .	6	8	16	6	SW	W. M. Schrock.
Tioga,	Wellsboro,[2]	1,327	63·6	92	24	38	7	. . .	. . .	. . .	. . .	1·89	. . .	. . .	7	10	12	8	N	H. D. Deming
Union,	Lewisburg (27 days),	450	68·1	95	23	42	7	80·1	56·1	24·0	36	2·39	. . .	. . .	10	12	8	7	W	Prof. W. G. Owens.
Wayne,	Dyberry,	1,100	64·8	92	23	30	7	78·6	50·9	27·7	46	2·86	. . .	. . .	13	11	11	8	NW	Theodore Day.
Wayne,	Honesdale,	1,000	67·0	89	24	35	7	77·8	56·2	21 6	36	3·10	. . .	. . .	16	13	9	8	NW	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	68·4	91	24, 30	40	8	77·7	59·2	18·5	29	3·11	. . .	. . .	16	4	18	8	W	T.B. Orchard, M.D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	69·8	93	25	42	7	79·2	60·4	18·8	26	1·66	. . .	. . .	5	. . .	. . .	. . .	. . .	Murray Forbes
Westmoreland,	Ligonier,	1,750	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	C. D. Ambrose.
Wyoming,	South Eaton,	660	67·3	91	24	39	7	77·6	56·8	21·0	32	1·09	. . .	. . .	6	14	12	4	SW	B. M. Hall.
York,	York,	385	70·2	96	24	42	7, 8	82·4	57·9	24·5	32	3·06	. . .	. . .	9	12	17	1	NW	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4 [2] Mean temperature 8 + 8 + 2.
‡ From 15th to 26th inclusive maximum temperature obtained from current readings.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Bloomiag Grove,	.24	.14	. .	.27	. .	. .	. .	. .	. .	. .	. .	1.06	. .	. .	. .	.40	. .	. .	.25	.10	. .	. .	. .	.65	. .	.16	.20	. .	. .	.04	. .	.51
Browers Lock,	. .	. .	. .	.19	.43	.40	. .	.21	. .	. .	. .	. .	.18	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1.76	. .	.07	. .	. .	.46	. .	.66
Coatesville,	. .	. .	. .	.10	.45	1.09	.08	.03	. .	. .	. .	. .	.20	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.20	. .	.14	. .	. .	. .	. .	. .	2.29
Coopersburg,	.01	.12	.03	.36	. .	.04	.16	. .	. .	. .	. .	. .	.09	. .	. .	.05	. .	.04	. .	.04	. .	. .	.04	1.38	. .	.07	.06	.04	. .	.05	. .	2.58
Doylestown,	. .	. .	. .	.13	. .	.26	.31	.13	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.20	.25	. .	. .	.09	. .	. .	. .	. .	1.35
Dyberry,	.16	.21	. .	.17	. .	. .	. .	. .	.07	. .	. .	.03	. .	. .	. .	. .	. .	.13	.15	.22	. .	. .	. .	.03	.21	.37	.20	. .	. .	.89	. .	2.86
Easton,	. .	. .	.34	.09	. .	.01	.02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.97	. .	. .	. .	. .	. .	. .	.59	. .	.28	.02	. .	.29	. .	2.54
Forks of Neshaminy,	.02	.01	.02	.03	.35	.52	.12	.06	. .	. .	. .	. .	.03	. .	. .	. .	. .	. .	.01	. .	. .	. .	.01	.38	. .	1.15	. .	. .	. .	1.12	. .	3.83
Frederick,	. .	. .	. .	.06	.17	.26	.24	. .	. .	. .	. .	. .	.10	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.92	. .	.05	.15	. .	. .	.96	. .	2.91
Hamburg,	.02	.03	.20	.12	. .	.05	.22	. .	. .	. .	. .	. .	.22	. .	.04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.28	. .	.22	. .	. .	. .	1.40
Honesdale,	1.9	.15	.01	.30	. .	.01	.16	. .	.08	. .	. .	.18	. .	. .	. .	. .	. .	.16	.40	.03	.05	. .	. .	. .	.19	.23	.59	. .	.46	.07	. .	3.10
Kennett Square,	. .	. .	. .	.18	.82	.84	.05	.13	. .	. .	. .	. .	.15	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.13	.01	.07	.09	. .	. .	. .	. .	2.45
Lansdale,	. .	. .	.03	. .	.39	.30	.22	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1.03	. .	.14	.11	. .	. .	.19	. .	2.47
Mauch Chunk,	. .	.09	.25	.23	. .	. .	.22	. .	. .	. .	. .	. .	.01	. .	. .	. .	. .	. .	. .	.38	. .	. .	.02	.03	. .	1.14	. .	.42	. .	.05	. .	2.87
Ottsville,	. .	.07	. .	.21	.07	.10	.01	.16	. .	. .	. .	. .	.09	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.45	. .	.02	.48	. .	. .	.83	. .	2.49
Philadelphia, a†	. .	. .	. .	.07	.65	.53	.08	. .	. .	. .	. .	. .	.02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.12	.01	.01	. .	. .	. .	.14	. .	1.03
Philadelphia, b,	. .	. .	. .	.05	.81	.54	.03	. .	. .	. .	. .	. .	.04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.06	. .	. .	. .	. .	. .	.83	. .	2.56
Philadelphia, c,	. .	. .	. .	.05	.76	1.47	.11	. .	. .	. .	. .	. .	.05	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.10	. .	.01	. .	. .	. .	.17	. .	2.74
Phoenixville,	.01	. .	. .	.15	.40	.52	.23	. .	. .	. .	. .	. .	.22	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	3.15	.02	.04	.14	. .	. .	.43	. .	5.31
Point Pleasant,	. .	.09	. .	.09	.10	.24	.44	.08	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.34	.68	.21	. .	. .	.32	. .	. .	. .	2.79
Pottstown,	. .	. .	.08	.12	.32	.30	.20	. .	. .	. .	. .	. .	.21	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.30	.02	.20	. .	. .	. .	.05	. .	1.74
Quakertown,	. .	.27	.10	.04	.13	.15	.21	.01	. .	. .	. .	. .	. .	. .	. .	.08	. .	. .	. .	. .	. .	. .	. .	1.00	. .	.09	.05	. .	. .	1.09	. .	3.22
Reading,	.01	.02	.04	.03	.04	.10	.11	. .	. .	. .	. .	. .	.24	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.05	. .	.25	. .	. .	. .	.02	. .	0.91
Salem Corners,	.22	.25	.04	.34	.01	. .	. .	. .	. .	. .	. .	. .	.45	. .	. .	. .	.01	. .	.50	.04	.03	.31	. .	. .	.62	.07	.16	.05	. .	.03	. .	3.13
Saltaltzville,	. .	. .	. .	.30	. .	.10	.28	. .	. .	. .	. .	.10	. .	. .	. .	. .	. .	.02	. .	. .	. .	. .	. .	1.76	. .	.03	. .	. .	. .	1.13	. .	4.32
Shippack,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Smith's Corner,	. .	.12	. .	.04	.09	.23	.12	.05	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.05	.54	. .	. .	.18	. .	. .	.51	. .	1.95
Swarthmore,	. .	. .	. .	.40	1.00	.08	. .	. .	. .	.02	.81	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.42	.02	. .	. .	. .	.78	. .	2.93
West Chester,	. .	.02	. .	.04	.07	.73	.06	. .	. .	. .	. .	. .	.27	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.50	.01	.03	.06	. .	. .	1.35	. .	3.74
Westtown,	. .	. .	. .	.05	.80	.75	.05	. .	. .	. .	. .	. .	.18	. .	. .	. .	. .	. .	. .	. .	. .	. .	.0	.73	. .	. .	.40	. .	. .	1.10	. .	4.08
Susquehanna Basin.																																
Altoona,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	2.66
Aqueduct,	.02	.18	.17	.06	. .	.04	.05	. .	. .	. .	. .	.16	.23	. .	. .	.84	. .	.01	.77	. .	. .	. .	. .	.05	. .	.20	. .	. .	. .	. .	. .	2.78
Bloomsburg,	.06	.40	. .	.34	. .	.20	. .	. .	. .	. .	. .	.02	.12	. .	. .	.08	. .	.47	.08	. .	. .	. .	. .	. .	.54	. .	. .	. .	. .	. .	. .	2.25
Carlisle,	.06	. .	. .	.02	. .	.04	.15	. .	. .	. .	. .	. .	.45	. .	. .	.44	. .	. .	. .	. .	. .	. .	. .	. .	. .	.85	.04	. .	. .	. .	. .	2.05
Drifton,	.20	.11	*	.57	. .	. .	.35	. .	*	. .	. .	. .	. .	. .	. .	. .	*	.62	.06	.15	. .	. .	.20	.12	. .	. .	.49	. .	. .	. .	. .	2.87
Emporium,	.10	.63	.01	.37	.06	. .	.06	. .	. .	. .	. .	1.14	. .	. .	. .	. .	.30	.05	. .	. .	. .	. .	. .	. .	.21	. .	.13	. .	. .	. .	. .	3.06
Gettysburg,	. .	. .	. .	. .	.36	.23	.12	.02	. .	. .	. .	. .	.44	. .	. .	.21	. .	.02	.04	. .	. .	. .	. .	. .	. .	. .	.24	. .	. .	. .	. .	. .	1.75
Girardville,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Grampian,	. .	. .	.34	.26	. .	. .	.07	. .	. .	. .	. .	. .	.14	. .	. .	.49	. .	.13	. .	. .	. .	. .	. .	. .	.43	. .	.21	. .	. .	. .	. .	2.07
Harrisburg,†	. .	. .	.05	.01	.02	.07	.02	.04	. .	. .	. .	. .	.10	.09	.16	1.31	. .	.32	. .	. .	. .	. .	. .	. .	. .	.86	. .	. .	. .	. .	. .	3.35
Hollidaysburg,	. .	.09	. .	.12	. .	.04	. .	. .	. .	. .	. .	. .	.18	. .	. .	.46	.17	.25	.05	. .	. .	1.62	.71	. .	.07	.11	. .	. .	. .	. .	. .	3.87
Huntingdon,	.10	.04	.10	.10	. .	.02	.07	. .	. .	. .	. .	. .	.35	. .	. .	.05	.80	.10	.07	. .	. .	. .	. .	.40	. .	.60	.63	. .	. .	. .	. .	3.56
Kilmer,	.08	. .	.43	.04	. .	.06	.14	. .	. .	. .	. .	.99	. .	. .	. .	.13	. .	. .	.71	. .	. .	. .	. .	.90	. .	. .	.19	. .	. .	. .	. .	3.05
Lancaster,	.01	. .	. .	.21	. .	.36	.03	. .	. .	. .	. .	.01	.28	. .	. .	.24	. .	. .	. .	. .	. .	. .	. .	. .	.48	. .	1.10	. .	. .	. .	. .	2.54
Lebanon,	.05	. .	.17	.16	.01	.05	.09	.03	. .	. .	. .	. .	.24	. .	. .	.17	. .	.08	. .	.62	. .	. .	. .	. .	. .	. .	.30	. .	. .	. .	. .	1.91
Le Roy,	.10	.16	. .	.06	.04	. .	.10	. .	. .	. .	. .	. .	.29	. .	. .	. .	.20	.21	.04	.07	. .	. .	. .	. .	.04	.28	. .	.05	. .	. .	. .	1.64
Lewisburg,	*	.21	. .	.27	. .	. .	.25	. .	. .	. .	. .	. .	.55	. .	*	.25	. .	.17	*	.15	. .	. .	. .	.48	.02	. .	.04	. .	. .	. .	. .	2.39
Lock Haven,	.33	.16	. .	. .	. .	.28	. .	. .	. .	. .	. .	1.12	. .	. .	. .	.74	.04	.12	. .	. .	. .	. .	. .	.23	.18	.31	. .	.01	. .	. .	. .	3.52
Selins Grove,	.20	.43	.09	.20	.08	. .	.19	. .	. .	. .	. .	. .	.43	. .	. .	.10	. .	. .	. .	. .	.10	.23	.35	. .	. .	. .	. .	. .	. .	. .	. .	2.40
South Eaton,	.03	.06	. .	.30	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.03	. .	. .	. .	. .	.24	.43	. .	. .	. .	. .	. .	. .	1.09
State College,	.02	.25	.09	.09	. .	. .	.08	. .	. .	. .	. .	. .	.15	.81	. .	.25	.10	1.88	.14	. .	. .	. .	.35	.01	.40	.06	.02	. .	. .	. .	. .	4.60
Wellsboro,	.05	.35	.09	.25	. .	. .	.20	. .	. .	. .	. .	. .	.93	. .	. .	. .	. .	.05	.15	. .	. .	. .	. .	. .	.77	. .	. .	. .	. .	. .	. .	1.89
Wilkes-Barre,	.17	.16	.67	. .	. .	. .	.03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.24	. .	. .	. .	. .	. .	.26	. .	1.78
York,	. .	. .	. .	.43	.40	.05	.17	. .	. .	. .	. .	. .	.37	.33	. .	.55	. .	.31	. .	. .	. .	. .	. .	. .	. .	.45	. .	. .	. .	. .	. .	3.06

†U. S. Weather Bureau Stations. *Missing. ‡Total rainfall from 1st to 5th, inclusive.

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URING JUNE, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,	. .	.18	.03	. .	.04	.02	. .	. .	. .	. .	. .	. .	.07	. .	. .	. .	. .	. .	.05	. .	. .	. .	. .	.03	.20	. .	.16	.49	.11	. .	. .	1.38
Brookville,	.32	.07	.41	.13	.03	.02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.14	. .	.54	.15	. .	. .	. .	. .	.07	.11	.04	. .	. .	. .	. .	2.03
Cassandria,	.23	.13	. .	.16	. .	.08	. .	. .	. .	. .	. .	. .	. .	. .	. .	.09	.08	. .	.13	. .	. .	.18	. .	. .	.55	. .	.04	. .	. .	. .	. .	1.27
Clarion,	.53	.10	.19	.63	.04	.05	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.25	. .	.13	.20	. .	. .	. .	. .	.30	.04	.39	. .	. .	. .	. .	2.85
Confluence,	.43	.34	. .	. .	.30	.25	.07	. .	. .	. .	. .	. .	.37	. .	. .	. .	. .	. .	.34	. .	. .	. .	. .	. .	.40	. .	.40	. .	. .	. .	. .	2.90
Davis Island Dam,	.10	.20	. .	.01	.15	.02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.0	. .	.14	. .	. .	. .	. .	. .	. .	.15	.12	. .	. .	. .	. .	0.96
DuBois,	.10	.10	.41	.12	. .	. .	.11	. .	. .	. .	. .	. .	. .	. .	. .	. .	1.35	. .	. .	.09	. .	.01	. .	. .	.15	.24	.13	. .	. .	. .	. .	3.41
Elwood Junction,	.07	.03	.03	. .	.04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.39	. .	.04	. .	. .	. .	. .	. .	.22	. .	.28	.25	.16	. .	. .	1.51
Freeport,	.15	.08	.04	. .	. .	.02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.07	. .	.26	. .	. .	. .	. .	. .	.30	.34	.37	. .	.04	. .	. .	2.27
Greensboro,	.08	.20	. .	. .	.45	.17	.01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.05	. .	. .	. .	. .	.25	.15	.20	. .	.08	.10	. .	. .	2.49
Greenville,	.06	.16	. .	. .	. .	. .	.04	. .	. .	. .	. .	. .	. .	. .	. .	.60	. .	. .	. .	. .	. .	. .	. .	.44	. .	. .	.18	.32	. .	. .	. .	1.70
Immel Reservoir,	. .	.30	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.88	. .	. .	. .	. .	. .	. .	. .	. .	.35	. .	. .	.04	. .	. .	. .	1.16
Indiana,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Johnstown,	.13	.01	.01	.10	.02	.02	.01	. .	. .	. .	. .	. .	. .	. .	. .	.10	. .	. .	.15	. .	. .	.12	.02	.03	.82	.02	.44	.12	. .	. .	. .	2.12
Kane,	.20	.04	.02	.16	.09	. .	.05	. .	. .	. .	. .	. .	.13	. .	. .	. .	. .	.13	.10	. .	. .	. .	. .	. .	.09	.35	.08	. .	. .	. .	. .	2.34
Ligonier,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Lock No. 4,	.04	.43	. .	. .	.10	.03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.06	. .	.57	. .	. .	. .	.54	. .	.08	.14	. .	.01	.38	. .	. .	2.38
Mahoning,	.26	.04	.10	.08	.04	.03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.41	. .	1.18	. .	. .	. .	. .	.08	.18	.19	.43	. .	. .	. .	. .	3.08
Meadville,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
New Castle,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Oil City,	.20	.07	.20	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.48	. .	.12	. .	. .	. .	. .	.13	. .	. .	.31	. .	.11	. .	. .	1.62
Parker's Landing,	.44	.03	.07	.26	.01	.06	. .	.01	. .	. .	. .	. .	. .	. .	. .	. .	1.61	. .	.01	. .	. .	. .	. .	. .	.86	.10	.17	. .	. .	. .	. .	3.63
Pittsburg,†	.12	.17	. .	.03	.03	. .	. .	. .	. .	. .	. .	.01	. .	. .	. .	.10	. .	.05	.01	. .	. .	. .	. .	. .	. .	. .	.00	. .	.01	.02	. .	0.61
Ridgway,	.14	.20	.65	.05	.04	. .	.01	.03	. .	. .	. .	.11	.01	. .	. .	. .	.14	. .	.24	. .	. .	. .	. .	. .	.24	.16	.27	. .	. .	. .	. .	2.19
Saegerstown,	.20	.04	. .	. .	.12	. .	.03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.60	.10	. .	. .	. .	. .	.15	. .	.10	. .	.25	. .	. .	. .	1.59
Saltsburg,	.30	.23	. .	. .	.25	.01	. .	.05	. .	. .	. .	. .	. .	. .	. .	. .	.13	. .	.22	. .	. .	. .	. .	. .	.60	.12	.16	.02	. .	. .	. .	1.99
Shingle House,	.17	.47	. .	.29	.12	. .	.24	. .	. .	. .	.36	.26	. .	. .	. .	. .	.30	.05	.27	. .	. .	. .	.18	. .	.32	.01	.13	. .	. .	. .	. .	3.36
Smethport,	.25	.60	. .	. .	. .	. .	.20	. .	. .	. .	.85	. .	. .	. .	. .	. .	.65	. .	.15	. .	. .	. .	.20	.20	.35	. .	.20	. .	. .	. .	. .	3.65
Somerset,	.15	. .	. .	.95	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1.15	. .	.52	. .	. .	. .	. .	. .	.20	. .	.35	. .	. .	. .	. .	3.37
Stoyestown,	.24	.08	.10	.07	.04	.03	.06	.12	. .	. .	. .	. .	. .	. .	. .	.51	.10	.28	. .	. .	. .	. .	.36	. .	.19	.21	.06	. .	. .	. .	. .	2.44
Uniontown,	*	*	*	*	1.70	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.02	.03	.65	. .	. .	. .	. .	. .	1.40
Warren,	.15	.23	.48	.02	.12	. .	. .	.05	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.52	.04	. .	. .	. .	. .	.93	.27	.28	. .	. .	. .	. .	3.09
West Newton,	.32	.28	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.18	. .	.60	. .	. .	. .	. .	. .	.07	.20	.10	. .	. .	. .	. .	1.75
Potomac Basin.																																
Chambersburg,	. .	. .	. .	. .	.48	.25	. .	. .	. .	. .	. .	. .	.58	. .	. .	. .	.01	.05	.02	. .	. .	. .	. .	. .	.75	1.03	. .	. .	. .	. .	. .	3.17
McConnellsburg,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Lake Basin.																																
Erie,†	.25	.79	.01	. .	.04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.01	.11	.32	. .	. .	. .	. .	.54	.06	.43	.14	. .	.16	. .	. .	2.88

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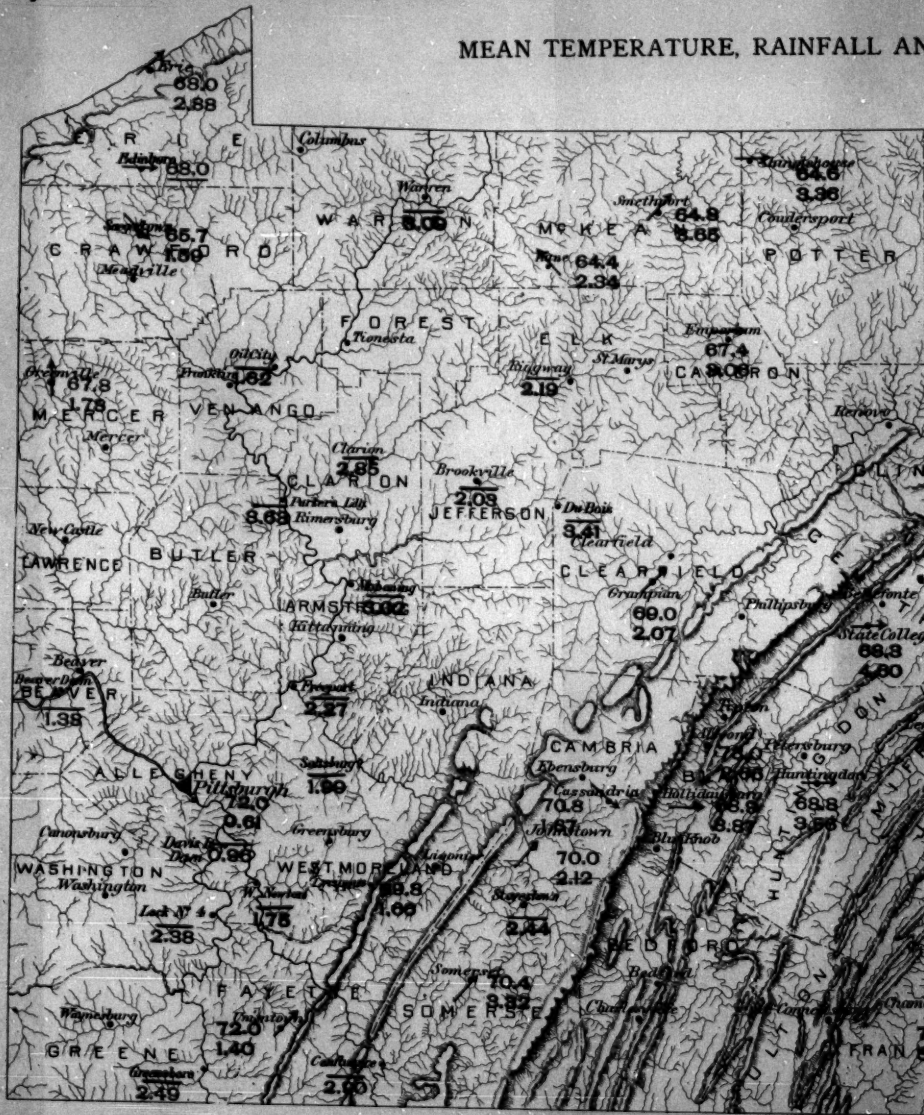

State Weather Service.

AND PREVAILING WIND DIRECTION FOR JUNE, 1894.

OBERLIN COLLEGE LIBRARY

AUGUST WEATHER.

From United States Weather Bureau Records.

The following data, compiled from the records of observations taken during the length of time given at each station, show the average and extreme conditions during that time, and also the range within which weather variations may be expected to keep in any future August.

	Philadelphia. (23 years.)	Pittsburgh. (23 years.)	Erie. (21 years.)
Mean or normal,	74°	72°	70°
Warmest August,	1871	1881	1881
Average,	77°	74°	73°
Coldest August,	1874	1874	1885
Average,	71°	69°	66°
Highest temperature recorded,	99°	100°	94°
Date,	13th, 1881	6th, 1881	4th, 1887
Lowest temperature recorded,	51°	45°	47°
Date,	24th, 1890	24th, 1890	28th, 1887
Average date of last "killing" frost (spring),	April 9th	April 27th	April 30th
Average precipitation (inches),	4·62	3·25	3·41
Average number of days with .01 inch or more,	11	8	10
Greatest monthly precipitation,	11·49	7·26	7·97
Date,	1873	1888	1885
Least monthly precipitation,	0·66	0·88	0·98
Date,	1877	1881	1876
Greatest amount in 24 hours,	5·21	3·65	3·11
Date,	12th and 13th, 1873	21st and 22d, 1888	16th, 1879
Average number clear days,	10	10	11
Partly cloudy,	11	14	13
Cloudy,	10	7	7
Prevailing direction of wind,	SW	NW	S
Highest velocity, miles per hour,	55	36	36
Date,	24th, 1893	4th, 1888	20th, 1891, 29th, 1893